OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
CALCULATION COVER SHEET

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2. Calculation Title
Supporting Rock Fall Calculation for Drift Degradation: Quantification of Uncertainties

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9. Remarks

The results provided in this document supersede the information in Input Transmittal 00453.T, *Rockfall Sensitivity Calculations*. While this calculation provides some additional information that was not in Input Transmittal 00453.T, the information contained in the Input Transmittal has not changed.

Revision History

10. Revision No.	11. Description of Revision
00	Initial issue.

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1. PURPOSE

The purpose of this calculation is to quantify previously unquantified uncertainties associated with the *Drift Degradation Analysis* (BSC 2001b). The results from this calculation will support the development of a technical report to document supplemental science and performance analyses.

This calculation has been developed according to the guidance provided by the *Technical Work Plan for EBS Department Modeling FY 01 Work Activities* (BSC 2001a). The specific objective of this calculation is to perform sensitivity studies to assess the impact of the following parameters on rock fall results:

- parameter M, a multiplier of fracture trace lengths sampled from field data
- Terzaghi correction factor for subhorizontal fractures
- number of Monte Carlo simulations.

The scope of this calculation includes using the fracture data inputs from the *Drift Degradation Analysis* (BSC 2001b) as input to the Discrete Region Key Block Analysis (DRKBA) numerical code. Outputs from this program includes the expected quantities and size distributions of failed rock blocks. This calculation is applicable to unsupported drifts without backfill.

This calculation is associated with the engineering and performance analysis activities of the Engineered Barrier System Department, and was developed in accordance with AP-3.12Q, *Calculations*.

2. METHOD

This activity involves using the software program DRKBA to perform calculations to determine the expected quantities and size distributions of failed rock blocks. Further details of the calculation methods are provided in Section 5. Electronic data used in the preparation of this calculation were obtained from the Technical Data Management System as appropriate. Electronic data were controlled and managed per the technical work plan (BSC 2001a). To ensure accuracy and completeness of the information generated by this report, access to the information on the personal computer used to develop this report is controlled with password protection. The personal computer files are stored on the network 'O' drive, which is backed up daily per project standards. Upon completion of this work, all files are transferred to a compact disk–read-only memory (CD-ROM), appropriately labeled, and verified by examining the file listing. Visual checks are conducted on print-outs. The CD-ROM is transmitted to Document Control for transfer to the Record Processing Center. During the process of checking the document, accuracy and completeness of the data retrieved and reported in this document is verified against the information placed in the Records Processing Center and project information databases as applicable.

3. ASSUMPTIONS

The following assumptions have been used in this calculation. No assumptions listed below need confirmation.

3.1 The positioning parameter required as joint parameter input is assumed to be the offset measured from the center of the trace length to the scan line of the detailed line survey. The basis of this assumption is that this is the best available way to represent the positioning parameter since the determination of the true positioning parameter requires the three dimensional information of the joint plane that is not available. This approach is considered conservative because the offset measured from the one dimensional scan line is smaller than the true offset in three dimensional space (i.e., the probability of forming key block is higher with smaller offset value). This assumption is used throughout.

3.2 The DRKBA software does not include a ground support element. All key blocks determined in this calculation are therefore the blocks that fail in an unsupported opening. This assumption is necessary due to the ground support limitation of the DRKBA program. The basis for this assumption is that it represents a bounding case, such that no blocks are prevented from failing by ground support. The assumption is used throughout.

3.3 The laboratory shear strength tests indicate the mean cohesion value of 0.86 MPa and the standard deviation of 0.81 MPa (see Table 6, Section 5.1). Due to the wide range of the standard deviation, the joint cohesion used in DRKBA rock fall model is conservatively initialized as 0.1 MPa. The basis for assuming an initial cohesion value of 0.1 MPa is that the wide range of values from test results (BSC 2001b, Attachment XIII) indicates some uncertainty in the true cohesion value; therefore, a value near the low end of the test results was selected for conservatism. This assumption is used throughout.

3.4 An emplacement drift azimuth of 72º was modeled in this calculation with drifts trending 75º. The basis for this assumption is that this 3-degree difference between the modeled and actual drift alignment is acceptable given the variability of joint set orientations captured in the model (see Section 5.2.2). The 3-degree difference does not significantly effect the results from this calculation. This assumption is used throughout.

4. USE OF COMPUTER SOFTWARE AND MODELS

4.1 QUALIFIED COMPUTER SOFTWARE

DRKBA Version 3.3 (CRWMS M&O 2000a, software tracking number: 10071-3.3-00) was used in parts of this calculation. DRKBA was used to assess the formation of blocks in the rock mass based on tunnel mapping data, and to analyze these blocks to determine if they are stable. DRKBA calculations were performed on a computer with a Pentium II microprocessor. DRKBA software is appropriate for the applications used in this supporting rock fall calculation for drift degradation. DRKBA was obtained from the Software Configuration Management in accordance with the applicable administrative procedures. DRKBA software was used only within the range of validation as specified in the software qualification documentation (CRWMS M&O 2000a). A complete listing of DRKBA input files used in this analysis is provided in Attachment I. The outputs are presented in Section 6. A complete listing of output files is also provided in Attachment I.

4.2 OTHER SOFTWARE

In addition to the above listed item, *Microsoft Excel 97 SR-2* was also used to perform support calculations as described in Section 5 and Attachment I of this document. *Excel* is a commercial off-the-shelf software program, and only the standard functions of *Excel* were used in this calculation. All results from the *Excel* calculations are not dependent on the software program itself. Attachment I provides documentation of the *Excel* calculations in sufficient detail to allow independent repetition of the computations in accordance with AP-3.12Q Attachment 2. Thus, the software use is considered exempt from the requirements of AP-SI.1Q, *Software Management*.

4.3 MODELS

The DRKBA rock fall model, as documented and validated in the *Drift Degradation Analysis* (BSC 2001b, Section 6), was used in parts of this calculation. The justification for use of the model is documented in the *Drift Degradation Analysis* (BSC 2001b, Section 6.5). The use of the model in this calculation is limited to varying model input parameters as described in Section 5.3, and documenting the subsequent change in model output. The software associated with the DRKBA rock fall model is DRKBA Version 3.3, which is described in Section 4.1.

5. CALCULATION

5.1 DATA AND PARAMETERS

The geotechnical parameters used in this calculation were developed in the *Drift Degradation Analysis* (BSC 2001b, Sections 4.1 and 6.3), and are based on data and information collected either by field mapping or by laboratory testing. The geotechnical data and their associated data tracking number (DTN) are presented in Tables 1 through 6. Developed joint geometrical data (BSC 2001b, pp. 38-39) were used as inputs for this calculation as shown in Tables 1 through 5 below. The developed joint data were based on qualified field mapping data collected from the Exploratory Studies Facility (ESF) in the Topopah Spring Tuff crystal poor upper lithophysal zone (Tptpul), middle nonlithophysal zone (Tptpmn), lithophysal zone (Tptpll), and lower nonlithophysal zone (Tptpln) lithologic units. It should be noted that subsequent studies by the U.S. Geological Survey/U.S. Bureau of Reclamation (USGS/USBR) have generated data on “small-scale” fractures with trace lengths less than 1 m (BSC 2001b, p. 21). The data collected from the small trace length fracture study have not been included this calculation. All data used in this calculation are qualified.

Table 1. Joint Set Orientation Data and Concentration Factors

Lithologic Unit	Joint Set Number	Mean Dip Direction (degrees)	Mean Dip (degrees)	Concentration Factor k
Tptpul	1	276	82	36.648
	2	300	82	20.576
	3	246	81	20.112
	4	211	83	22.425
	5	40	14	16.393
	6	37	47	24.210
	Random	263	70	1.850
Tptpmn	1	221	84	31.586
	2	299	83	26.143
	3	59	9	18.210
	Random	267	79	2.896
Tptpll	1	235	82	27.529
	2	270	79	24.723
	3	45	5	30.375
	Random	230	79	2.497
Tptpln	1	226	79	51.826
	2	299	82	23.304
	3	60	13	49.993
	Random	262	79	3.583

DTN: MO0109RDDAAMRR.003 (BSC 2001b, p. 38)

Table 2. Beta Distribution Parameters for Tptpul Unit

Joint Set Number	Parameters	a (m)	b (m)	p	q
1	Spacing	0.0132	16.3307	0.4223	1.5728
	Radius	2.0000	47.1800	0.2137	1.7194
	Positioning	0.0050	9.1500	0.2216	1.9098
2	Spacing	0.0015	16.3325	0.4073	1.3699
	Radius	2.0000	43.8000	0.3937	4.0620
	Positioning	0.0050	6.8500	0.4098	3.8946
3	Spacing	0.0083	16.4285	0.3545	1.1899
	Radius	2.0000	35.6000	0.3844	2.9909
	Positioning	0.0000	6.7500	0.4169	3.3486
4	Spacing	0.0098	16.0907	0.4500	1.3407
	Radius	1.8400	32.9000	0.3264	2.0332
	Positioning	0.0000	7.0000	0.2718	2.1962
5	Spacing	0.0295	14.3903	0.3171	1.1136
	Radius	2.0800	42.2000	0.4845	1.8767
	Positioning	0.0900	7.4500	0.5098	2.0530
6	Spacing	0.0070	16.4655	0.4063	1.0548
	Radius	2.1200	58.4000	0.5676	1.6409
	Positioning	0.0000	9.1500	0.3000	0.8489
Random	Spacing	0.0100	15.8700	0.6101	1.5645
	Radius	1.6400	58.0600	0.2448	2.0376
	Positioning	0.0000	9.1500	0.2186	1.6597

DTN: MO0109RDDAAMRR.003 (BSC 2001b, p. 38)

Table 3. Beta Distribution Parameters for Tptpmn Unit

Joint Set Number	Parameters	a (m)	b (m)	p	q
1	Spacing	0.0008	13.9199	0.2322	5.1372
	Radius	1.8200	108.0000	0.6554	20.7171
	Positioning	0.0000	9.1500	0.7569	10.2825
2	Spacing	0.0033	16.5306	0.4098	3.0879
	Radius	1.6400	141.0600	0.2024	7.2515
	Positioning	0.0000	9.1500	0.3292	4.0327
3	Spacing	0.0018	15.2606	0.2010	5.2988
	Radius	0.3200	101.6000	0.5503	8.5360
	Positioning	0.0150	9.1500	0.6369	4.6763
Random	Spacing	0.0100	15.1900	0.5279	7.6008
	Radius	1.3000	60.6000	0.6333	9.2812
	Positioning	0.0000	9.1500	0.5735	7.6186

DTN: MO0109RDDAAMRR.003 (BSC 2001b, p. 39)

Table 4. Beta Distribution Parameters for Tptpll Unit

Joint Set Number	Parameters	a (m)	b (m)	p	q
1	Spacing	0.0123	15.7210	0.3070	1.1475
	Radius	1.9000	47.0000	0.3332	1.7478
	Positioning	0.0000	8.2500	0.3443	1.5890
2	Spacing	0.1339	13.6172	0.7050	1.7231
	Radius	2.0400	32.8000	0.1833	0.7549
	Positioning	0.0050	7.2000	0.2507	1.0294
3	Spacing	0.0293	13.7779	0.1385	0.5149
	Radius	3.0800	90.0000	0.1378	0.8908
	Positioning	0.1800	9.1500	0.3089	1.0130
Random	Spacing	0.0500	16.4900	0.5816	1.6822
	Radius	1.7200	53.2400	0.2378	2.3364
	Positioning	0.0000	9.1500	0.2141	2.0886

DTN: MO0109RDDAAMRR.003 (BSC 2001b, p. 39)

Table 5. Beta Distribution Parameters for Tptpln Unit

Joint Set Number	Parameters	a (m)	b (m)	p	q
1	Spacing	0.0094	14.9637	0.1695	1.6013
	Radius	1.9800	29.6000	0.2850	0.9917
	Positioning	0.0150	5.6500	0.2812	1.0604
2	Spacing	0.0417	13.3921	0.2965	1.3043
	Radius	1.8800	51.6000	0.1993	1.1523
	Positioning	0.0600	8.1000	0.1983	0.8379
3	Spacing	0.0230	12.9674	0.2935	1.0515
	Radius	2.0200	10.6000	0.0993	0.6935
	Positioning	0.2150	1.5500	0.9565	2.0600
Random	Spacing	0.0300	10.5800	0.7008	2.1191
	Radius	1.7800	31.7000	0.1814	0.6253
	Positioning	0.0150	7.0750	0.2266	0.9275

DTN: MO0109RDDAAMRR.003 (BSC 2001b, p. 39)

Table 6. Inputs for Joint Strength Parameters

Parameter	Cohesion (MPa)	Friction Angle (degree)
Mean	0.86	41
Standard Deviation	±0.81	±3

DTN: MO0109RDDAAMRR.003 (BSC 2001b, p. 23 and Attachment XIII)

Rock density data were obtained from the laboratory tests performed on the rock cores from the North Ramp geotechnical (NRG) and the systematic drilling (SD) boreholes. The mean saturated bulk density (r) of 2.41 g/cm^3 for Tptpln unit, as developed in the *Drift Degradation Analysis* (BSC 2001b, p. 23 and Attachment XIII), was used in the calculation.

Joint strength parameters, including cohesion and friction angle, were developed in the *Drift Degradation Analysis* (BSC 2001b, Attachment XIII) based on laboratory shear strength test data from core specimens. Mean value and standard deviation (see Table 6 in this section) are required as the inputs for the DRKBA software. In the DRKBA rock fall model, the joint cohesion is conservatively scaled down to 0.1 MPa from 0.86 MPa listed in Table 6 (see Assumption 3.3).

5.2 DRKBA ROCK FALL MODEL

The DRKBA rock fall model used in this calculation was developed as part of the *Drift Degradation Analysis* (BSC 2001b). DRKBA input files were developed as described below and listed in Attachment I. The resulting output files are also listed in Attachment I and summarized in Section 6.

5.2.1 DRKBA Approach

DRKBA is a commercially available acquired software product (as described in Section 4). The software simulates structural discontinuities as circular discs placed in the rock mass according to probabilistic distributions determined from tunnel mapping data. Joint planes are simulated by a Monte Carlo technique from probability distributions representing the orientation, spacing, and trace length of the corresponding joint set. DRKBA then analyzes these blocks to determine whether they are geometrically feasible and to determine whether they are mechanically stable.

The DRKBA software requires four sets of data. The required data are stored in data files having extensions .mkg, .exc, .den, and .prb, and contain information for the grid, excavation, rock density, and joint sets, respectively. The make grid file (.mkg) includes the information required for building a grid of nodal points for the mesh. The excavation data file (.exc) contains the information for defining an excavation in three dimensional space. The density file (.den) holds the information for the rock density data. The probabilistic joint data file (.prb) includes the required information for generating fracture space from the given fracture probability distributions.

The DRKBA software employs a bipolar Watson distribution for joint orientation data. The principal axis orientation and a concentration factor k are the required inputs for the bipolar Watson distribution. The concentration factor k is an index of the concentration. The larger the value of k, the more the distribution is concentrated towards the principal axis orientation. Joints are represented as circular discs in the DRKBA analysis. Joint radii, spacings, and positioning are simulated with Beta distributions. The Beta distribution is a four-parameter distribution with the parameters a, b, p, and q. The parameters a and b represent the ends of the closed interval upon which the Beta distribution is defined. The parameters p and q determine the shape of the distribution curve, their values were calculated from the mean and standard deviation of the transformed data. The transformed data were obtained by normalizing the data with the maximum value. The cohesion and friction angle of the joints are simulated as a bivariate normal distribution. Inputs for the mean and standard deviation of the joint strength parameters are required.

5.2.2 Statistical Representation of Joint Data

Joint sets have been identified in a separate fracture geometry analysis based on clustering of the data from joint normal vectors plotted on stereonets (CRWMS M&O 2000b, Figures III-1 to III-4). In addition to the primary joint sets identified, a random joint set has also been simulated to account for any joint that is present in the rock mass but not accounted for in the primary sets (see Section 5.1, Table 1). The dispersion of the individual joints about their associated joint set axes was modeled by a Watson bipolar distribution for axial data. This probability distribution is characterized by a unit normal vector representing the mean direction about which the data is clustered and a concentration factor k representing the degree to which the data is clustered about the mean direction. The concentration factors were calculated based on the eigenvalues and eigenvectors of the orientation matrix (BSC 2001b, p. 33). The calculated concentration factors are also listed in Section 5.1 (Table 1).

Joint radii, spacings, and positioning are simulated with Beta distributions. The offset measured from the center of the trace length to the scan line was used as the positioning parameter. The parameters a, b, p and q for each lithologic unit are listed in Section 5.1 (Tables 2 to 5).

Cohesion and friction angle of the joints are simulated with the bivariate normal distribution. Mean and standard deviation for the cohesion and friction angle are presented in Section 5.1 (Table 6).

5.2.3 Excavation Modeling

As discussed in Assumption 3.4 (Section 3), the excavation in this calculation is a horizontal 5.5-m diameter emplacement drift trending 75° in accordance with the repository design description (BSC 2001c, p. 29; note that for the trend of the drift, 252° is equivalent to 72° since 252°–180°=72°). For each Monte Carlo simulation, a 24.4-m-long (80-ft) tunnel has been modeled in three-dimensional space. A circular tunnel opening without backfill was modeled. In the software, 18 plane equations were used to describe the circumference of the circular tunnel, and 2 plane equations were used to describe each end of the tunnel. The selection for the length of the tunnel modeled and the number of planes for simulation of the circular opening were based on the computer run time and the accuracy of the simulation. Calculations for the plane equations are included in the *Drift Degradation Analysis* (BSC 2001b, Attachment XV, electronic file, *Exca vectors V1.xls*). The region around the excavation has been modeled with a grid consisting of 681,472 nodes. The nodes are spaced 0.3 m (1 ft) apart, with each node representing 0.028 cubic meters (1 cubic foot) of the rock mass. The resolution of the mesh with a node spacing of 0.3 m was considered sufficient for calculating rock blocks since all joint trace lengths (as indicated by the radius parameter in Section 5.1, Tables 2 through 5) are greater than 1 m based on the field mapping data presented in Section 5.1.

5.3 PARAMETERS AFFECTING UNCERTAINTY

This calculation is limited to quantifying previously unquantified uncertainties associated with the rock fall model. Selected for quantification are uncertainties in values for M, a multiplier of fracture trace lengths to determine the radius of the joint plane, and for a Terzaghi correction for subhorizontal fractures in the DRKBA model. Uncertainty in the range of fracture variability was also selected. Quantification was done at the subsystem level with sensitivity studies on M, the Terzaghi correction, and the number of Monte Carlo simulations.

5.3.1 Fracture Size

Joint planes are represented as circular discs in the DRKBA rock fall model with the assumption that the radius of the joint plane is equal to twice the mapped trace length (BSC 2001b, Section 5.1). The multiplier, M, is used to obtain the radius of the circular fracture disc from the trace length as follows:

$$R = M * TL$$

where R = radius of the circular fracture disc, and
TL = trace length of the mapped fracture.

As indicated above, previous rock fall analyses have been conducted with a value of M set equal to 2.0 (BSC 2001b, Section 5.1). To document the sensitivity of the size of the joint plane in the DRKBA rock fall model, a series of rock fall calculations was developed for the Tptpmn and Tptpll units, with the joint radius multiplier, M, incrementally varied for each calculation. Values of M were set equal to 1.0, 1.5, 2.0, 2.5, and 3.0. Each calculation included 400 Monte Carlo simulations for both the Tptpmn and Tptpll units. It should be noted that 400 Monte Carlo simulations were shown to be adequate in the *Drift Degradation Analysis* (BSC 2001b, Attachment IV). Additional sensitivity calculations on the number of Monte Carlo simulations is described in Section 5.3.2.

With the exception of the joint radius, all other inputs for these calculations were consistent with inputs for the static condition presented in the *Drift Degradation Analysis* (BSC 2001b, Sections 6.3.1, 6.3.2, and 6.3.3). The calculation of beta parameters (see Section 5.2.2) for the joint radius is detailed in Attachment I (files *Tptpmn with various radius multiplier.xls* and *Tptpll with various radius multiplier.xls*). An example to describe the beta parameter calculation approach is provided in the *Drift Degradation Analysis* (BSC 2001b, Attachment III). The DRKBA input and output files, and associated calculation files to process and summarize the DRKBA results, are provided in Attachment I.

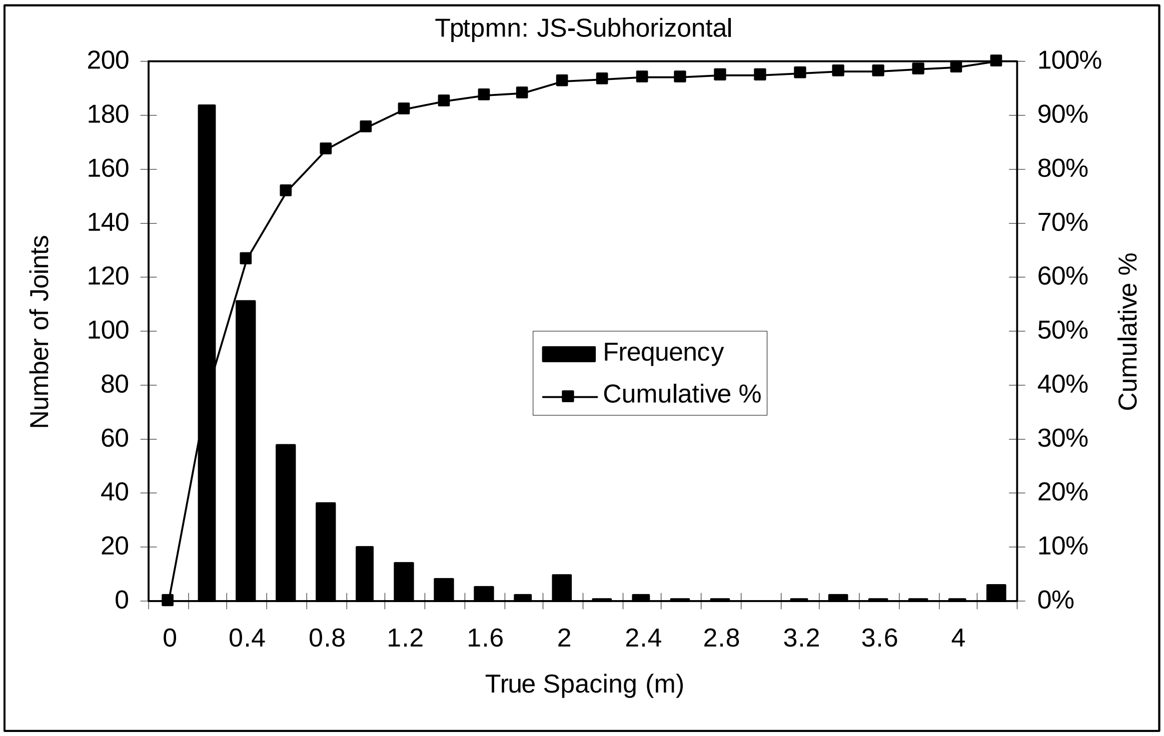
5.3.2 Number of Monte Carlo Simulations

In a DRKBA analysis, random joint patterns are generated with joint centers positioned in three-dimensional space, considering each joint set in sequence for each Monte Carlo simulation. The forming of key blocks is therefore different in each Monte Carlo simulation. To document the sensitivity of the number of Monte Carlo simulations for the analyses, a series of test runs was conducted. The test runs are intended to show the sensitivity of the number of Monte Carlo simulations in the prediction of the block size distribution, the prediction of the maximum block size, and the prediction of the number of blocks. Test runs were conducted for the Tptpul, Tptpmn, Tptpll, and Tptpln units with 100, 200, 400, 600, and 800 Monte Carlo simulations. The DRKBA input and output files, and associated calculation files to process and summarize the DRKBA results, are provided in Attachment I.

5.3.3 Terzaghi Correction for Spacing of Subhorizontal Fractures

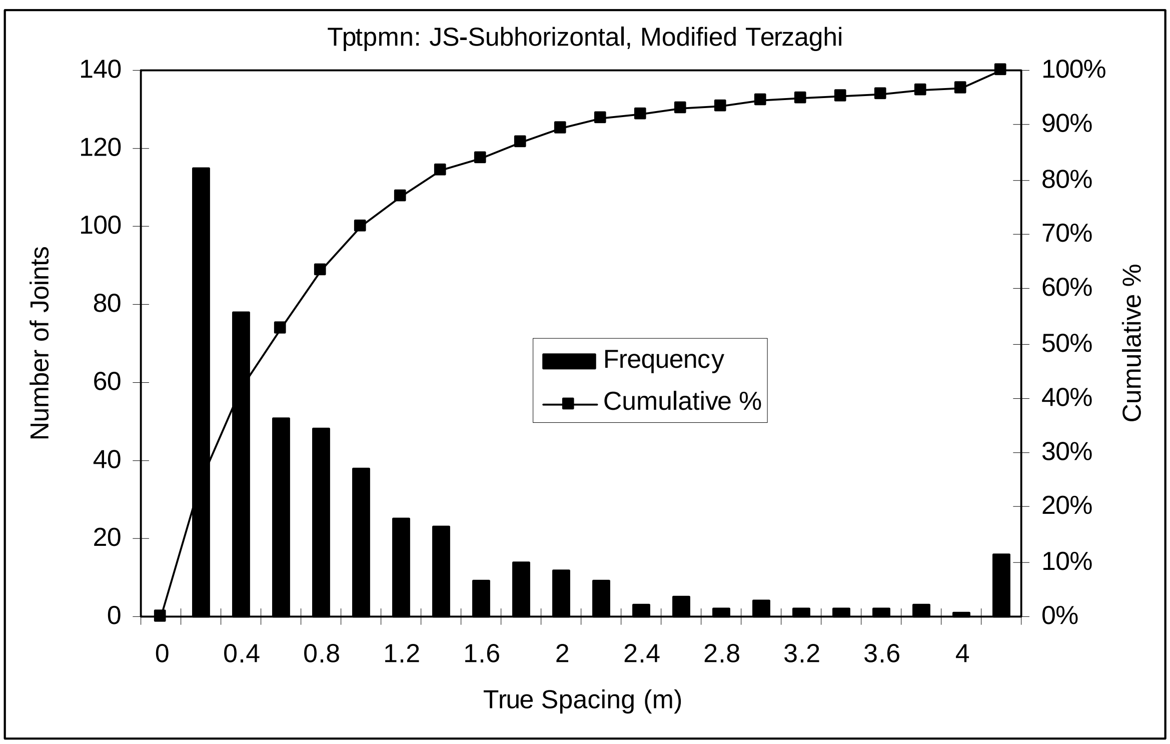
The procedure for determining joint set spacing is documented in the *Fracture Geometry Analysis for the Stratigraphic Units of the Repository Host Horizon* (CRWMS M&O 2000b, Section 6.4.2). A Terzaghi correction, which is a mathematical correction to determine the "true" spacing measured normal to the joint plane, has been applied to the mapped joint spacing data. For vertical joints striking perpendicular to the axis of the tunnel, the Terzaghi correction factor would be 1; that is, the mapped spacing is equal to the true spacing without a correction. Correction factors are most significant for subhorizontal fractures. For the subhorizontal fracture set from mapped fractures in the Tptpmn unit, the average Terzaghi correction factor is approximately 15, indicating that the true spacing of subhorizontal joints is 15 times less than the mapped spacing (Attachment I, file *Correction Factor Comparison.xls*). These Terzaghi correction factors with an average of approximately 15 were used in the *Drift Degradation Analysis* (BSC 2001b, Sections 4.1 and 6.3.2). For joints mapped along a horizontal scanline, a subhorizontal joint dipping 8 degrees or more will have a maximum Terzaghi correction factor of approximately 7 (i.e., $1/(\sin 8) \approx 7$). For joints dipping less than 8 degrees, the Terzaghi correction factor ranges from 7 to infinity. Therefore, the uncertainty associated with the correction factor increases within this range. It should be noted that true joint spacings greater than 16.5 m were not included in the spacing data set (CRWMS M&O 2000b, Section 6.4.2.1).

To document the sensitivity of the DRKBA rockfall model to the Terzaghi correction factor, calculations were conducted with a maximum correction factor of 7. To be consistent with the original approach, all calculated true spacings greater than 16.5 m were omitted from the joint spacing data set. The joint spacing distributions for the original true joint spacing and the modified true spacing (i.e., with a Terzaghi correction factor # 7) are shown in Figures 1 and 2, respectively, for the Tptpmn unit, and in Figures 3 and 4 for the Tptpll unit. The beta distribution parameters for joint spacing, which are required input for the DRKBA program, are provided in Table 7 for the Tptpmn and Tptpll units. The details for the calculation of each beta parameter are provided in Attachment I (files *New_Beta_Tptpmn V1 - modified Terzaghi.xls* and *New_Beta_Tptpll V1 - modified Terzaghi.xls*). Each DRKBA run included 400 Monte Carlo simulations for both the Tptpmn and Tptpll units. With the exception of the beta distribution parameters for the subhorizontal joint set of the Tptpmn and Tptpll units, all other inputs for these calculations were consistent with inputs for the static condition presented in the *Drift Degradation Analysis* (BSC 2001b, Sections 6.3.1, 6.3.2, and 6.3.3). The DRKBA input and output files, and associated calculation files to process and summarize the DRKBA results, are provided in Attachment I.



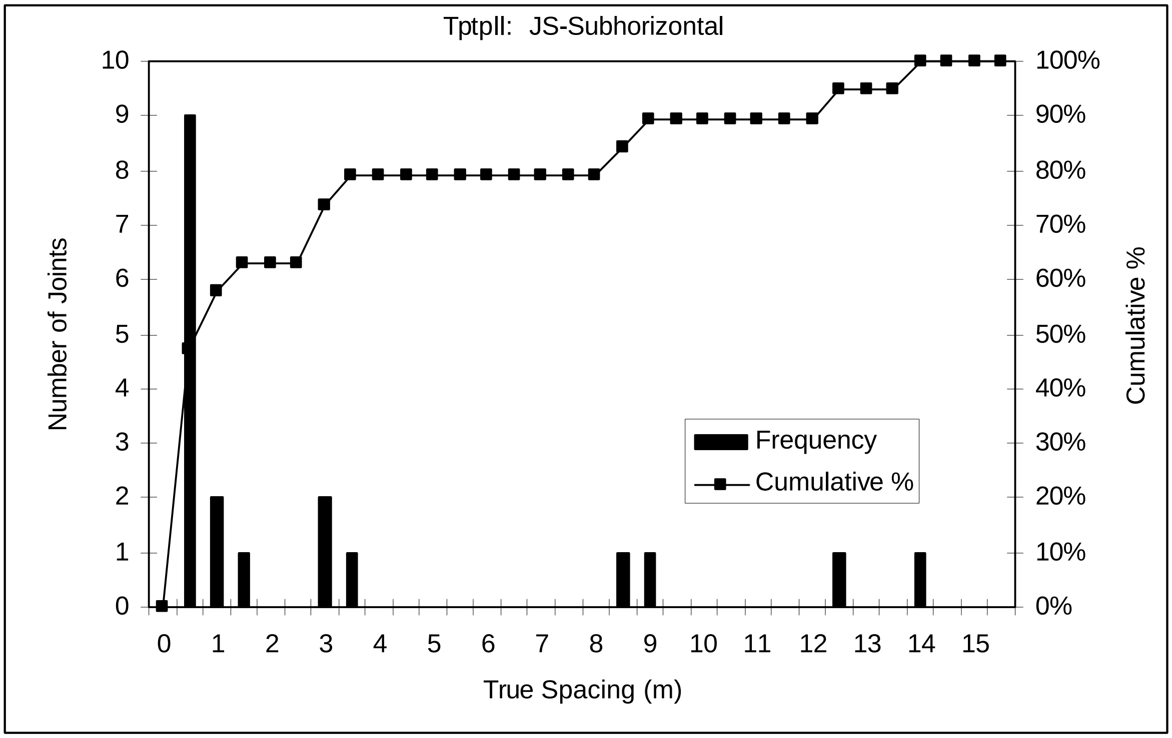
DTN: MO0110RPCRFCDD.001

Figure 1. Histogram and Cumulative Frequency Distribution of Fracture Spacing Data for the Tptpmn Unit Subhorizontal Joint Set, Original True Spacing (Attachment I, file *Tptpmn sub H Terzaghi.xls*)



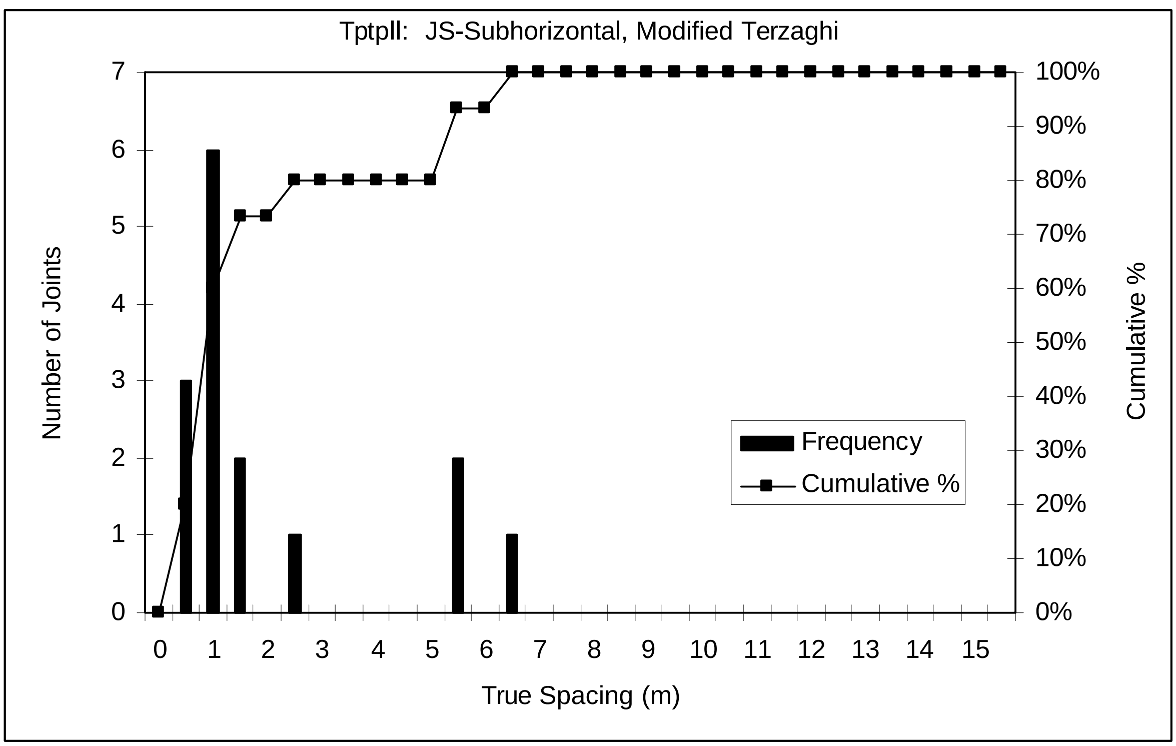
DTN: MO0110RPCRFCDD.001

Figure 2. Histogram and Cumulative Frequency Distribution of Fracture Spacing Data for the Tptpmn Unit Subhorizontal Joint Set, Modified True Spacing (Attachment I, file *Tptpmn sub H Terzaghi.xls*)



DTN: MO0110RPCRFCDD.001

Figure 3. Histogram and Cumulative Frequency Distribution of Fracture Spacing Data for the Tptpll Unit Subhorizontal Joint Set, Original True Spacing (Attachment I, file *Tptpll sub H Terzaghi.xls*)



DTN: MO0110RPCRFCDD.001

Figure 4. Histogram and Cumulative Frequency Distribution of Fracture Spacing Data for the Tptpll Unit Subhorizontal Joint Set, Modified True Spacing (Attachment I, file *Tptpll sub H Terzaghi.xls*)

Table 7. Beta Distribution Parameters for True Spacing of the Subhorizontal Joint Set

Beta Distribution Parameters	Tptpmn		Tptpll	
	Original[1]	Modified[2]	Original[3]	Modified[4]
a (m)	0.0018	0.0018	0.0293	0.0586
b (m)	15.2606	15.2606	13.7779	6.0429
p	0.2010	0.3834	0.1385	0.1961
q	5.2988	5.8050	0.5149	0.5023

[1]Table 3, Joint Set Number 3. DTN: MO0110RPCRFCDD.001
[2] Attachment I, file *New-Beta-Tptpmn V1 - modified Terzaghi.xls*.
[3]Table 4, Joint Set Number 3.
[4] Attachment I, file *New-Beta-Tptpll V1 - modified Terzaghi.xls*.

6. RESULTS

The results from this calculation are presented below as a function of the parameter evaluated. The data developed in this calculation have been entered into the Technical Data Management System (DTN: MO0110RPCRFCDD.001).

6.1 FRACTURE SIZE RESULTS

The results for the sensitivity of the size of the joint plane in the DRKBA rock fall model are provided in this section. Fracture size results were calculated according to the approach described in Section 5.3.1. Figures 5 and 6 present the DRKBA results in the format of cumulative frequency of occurrence for the Tptpmn and Tptpll units. The cumulative frequencies of occurrence corresponding to 50, 75, 90, 95 and 98 percentile block volume for each unit are listed in Tables 8 and 9. The maximum block sizes predicted from the analyses are also presented in these tables. The predicted numbers of key blocks per unit length of emplacement drift are listed in Table 10.

6.2 MONTE CARLO RESULTS

The results for the sensitivity of the number of Monte Carlo simulations are provided in this section. Monte Carlo results were calculated according to the approach described in Section 5.3.2. The results for the Tptpul, Tptpmn, Tptpll, and Tptpln units are shown in Figures 7 through 18, and include block size distribution curves in the form of cumulative frequency of occurrence, the predicted numbers of blocks per 10 simulations, and the maximum block sizes predicted for each case.

6.3 TERZAGHI CORRECTION RESULTS

The results for the sensitivity of the correction for spacing of subhorizontal joints are provided in this section. Terzaghi correction results were calculated according to the approach described in Section 5.3.3. Figures 19 and 20 present the key-block analysis results in the format of cumulative frequency of occurrence for the Tptpmn and Tptpll units, respectively. The cumulative frequencies of occurrence corresponding to 50, 75, 90, 95 and 98 percentile block volume for the Tptpmn and Tptpll units are listed in Table 11. The maximum block sizes predicted from the analysis are also presented in this table. The predicted numbers of key blocks per unit length of emplacement drift are listed in Table 12.

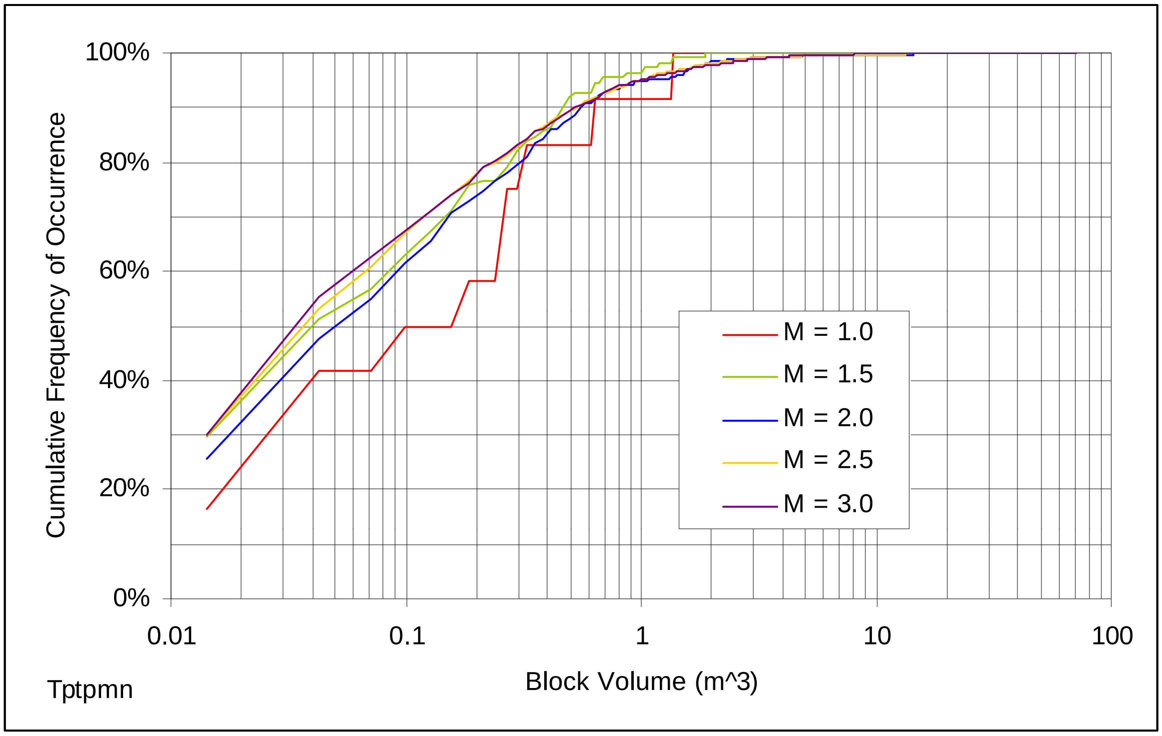


Figure 5. Cumulative Key-Block Size Distribution for Various Sizes of Joint Planes in the Tptpmn Unit, 75°-Azimuth (Attachment I, file *tpmn stat 75 trace length res v1.xls*)

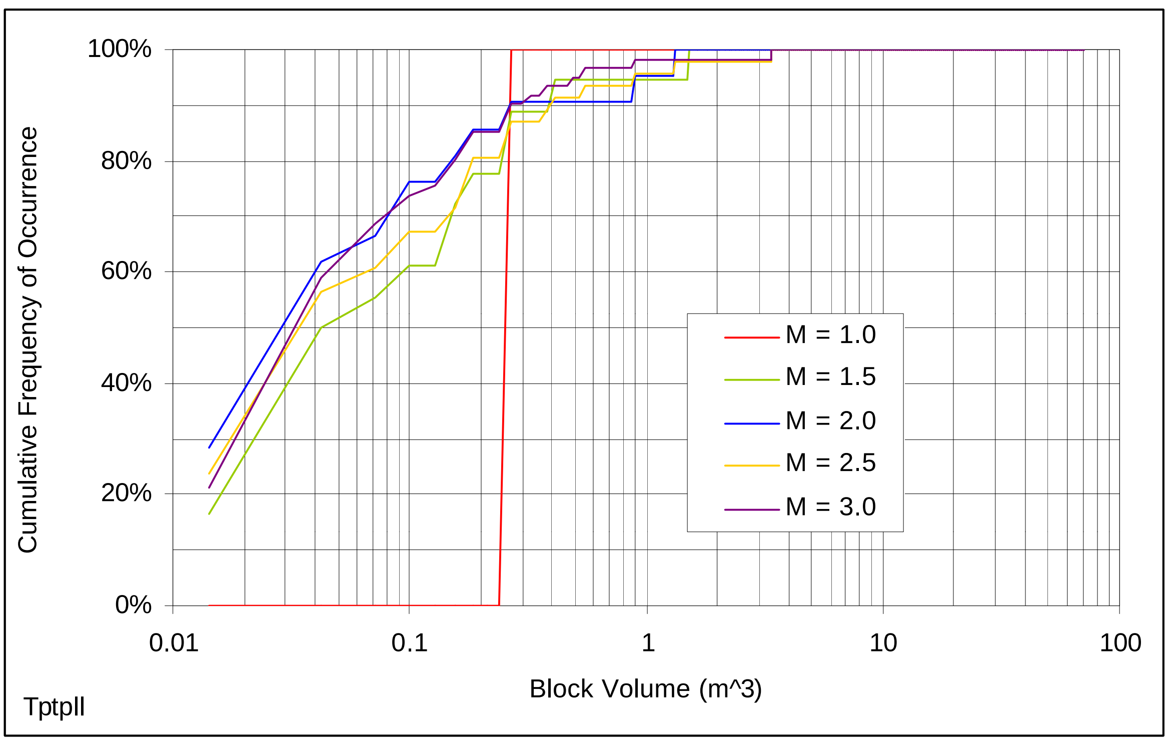


Figure 6. Cumulative Key-Block Size Distribution for Various Sizes of Joint Planes in the Tptpll Unit, 75°-Azimuth (Attachment I, file *tpll stat 75 trace length res v1.xls*)

Table 8. Block Volume (in cubic meters) Corresponding to Various Levels of Predicted Cumulative Frequency of Occurrence, Emplacement Drift in Tptpmn Unit, Static Condition (Attachment I, file *tpmn stat 75 trace length res v1.xls*)

Cumulative Frequency of Occurrence (%)	**Joint Radius Multiplier, M**				
	1.0	**1.5**	**2.0**	**2.5**	**3.0**
50	0.16	0.01	0.04	0.01	0.01
75	0.30	0.16	0.21	0.16	0.16
90	0.61	0.44	0.55	0.52	0.50
95	1.35	0.67	1.06	0.98	0.98
98	1.35	1.18	1.86	1.86	2.17
maximum	1.35	1.86	14.30	20.87	13.05

Table 9. Block Volume (in cubic meters) Corresponding to Various Levels of Predicted Cumulative Frequency of Occurrence, Emplacement Drift in Tptpll Unit, Static Condition (Attachment I, file *tpll stat 75 trace length res v1.xls*)

Cumulative Frequency of Occurrence (%)	**Joint Radius Multiplier, M**				
	1.0	**1.5**	**2.0**	**2.5**	**3.0**
50	0.24	0.04	0.01	0.01	0.01
75	0.24	0.16	0.07	0.16	0.10
90	0.24	0.38	0.24	0.38	0.24
95	0.24	1.49	0.86	0.86	0.47
98	0.24	1.49	1.29	3.36	0.86
maximum	0.24	1.49	1.29	3.36	3.36

Table 10. Predicted Number of Key Blocks per Unit Length (km) along Emplacement Drift, Static Condition (Attachment I, files *tpmn stat 75 trace length res v1.xls* and *tpll stat 75 trace length res v1.xls*)

Lithologic Unit	**Joint Radius Multiplier, M**				
	1.0	**1.5**	**2.0**	**2.5**	**3.0**
Tptpmn	1	11	50	152	265
Tptpll	0	2	2	5	6

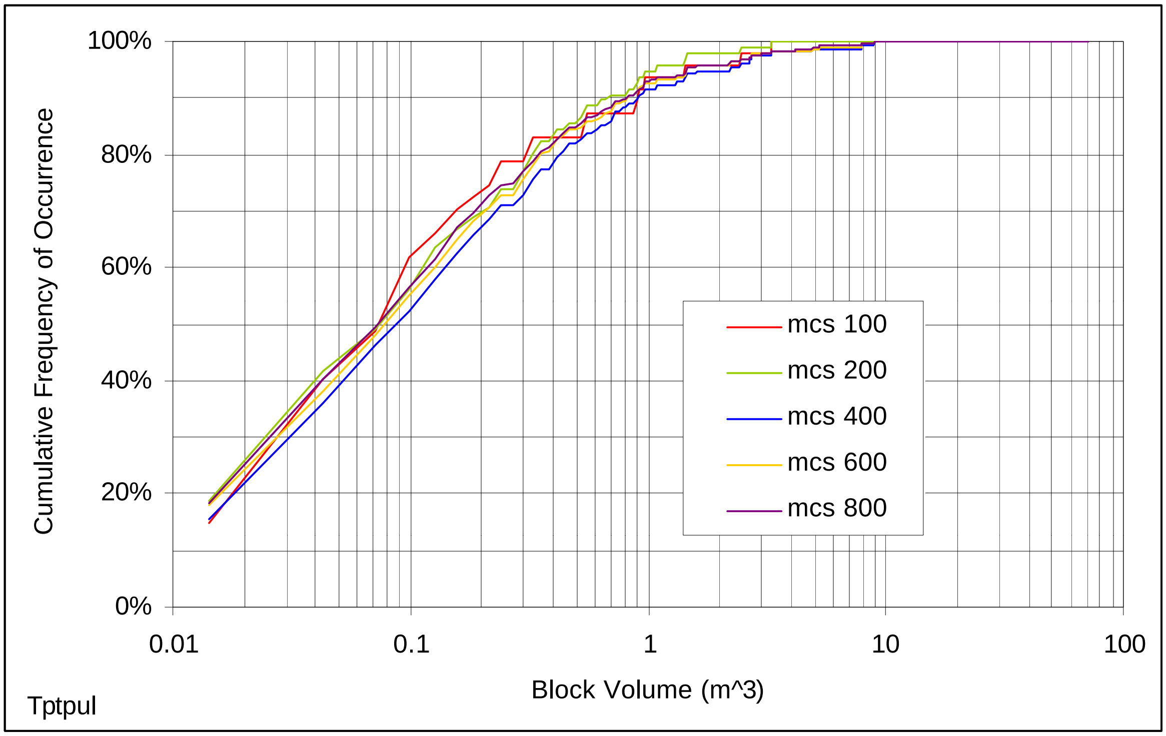


Figure 7. Block Size Distributions for Various Monte Carlo Simulations in the Tptpul Unit (Attachment I, file *mcs sensitivity study Tptpul v1.xls*)

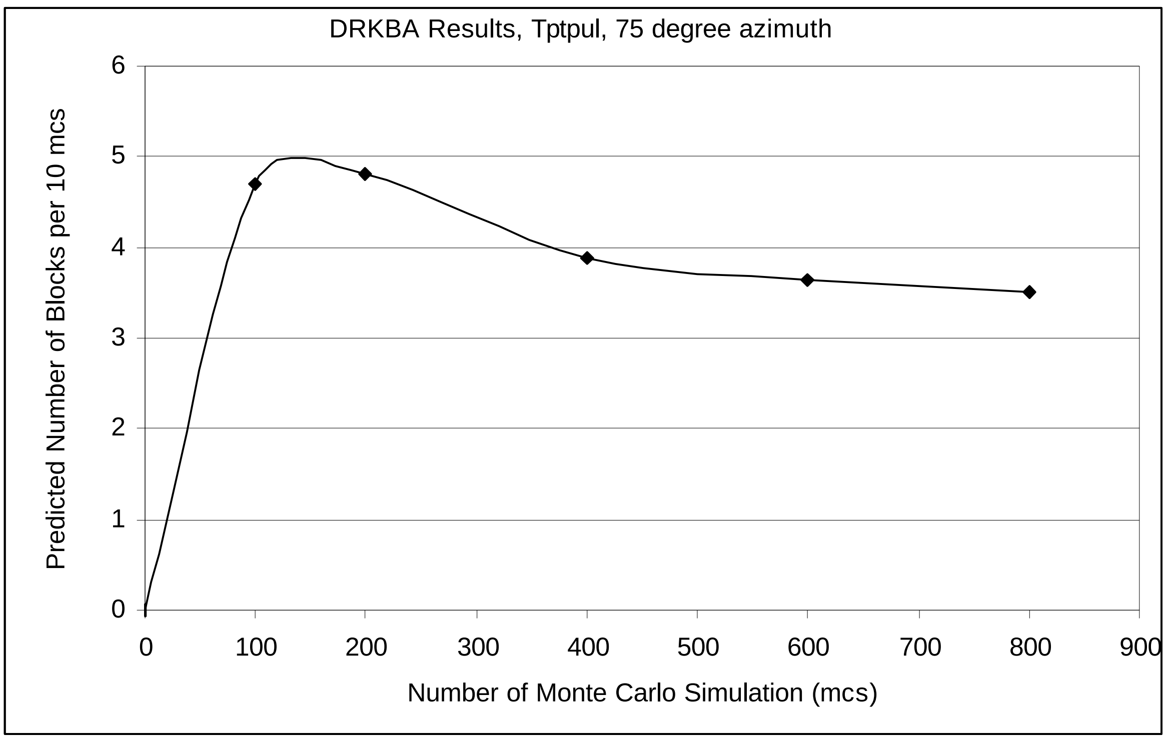


Figure 8. Predicted Number of Key Blocks for Various Monte Carlo Simulations in the Tptpul Unit (Attachment I, file *mcs sensitivity study Tptpul v1.xls*)

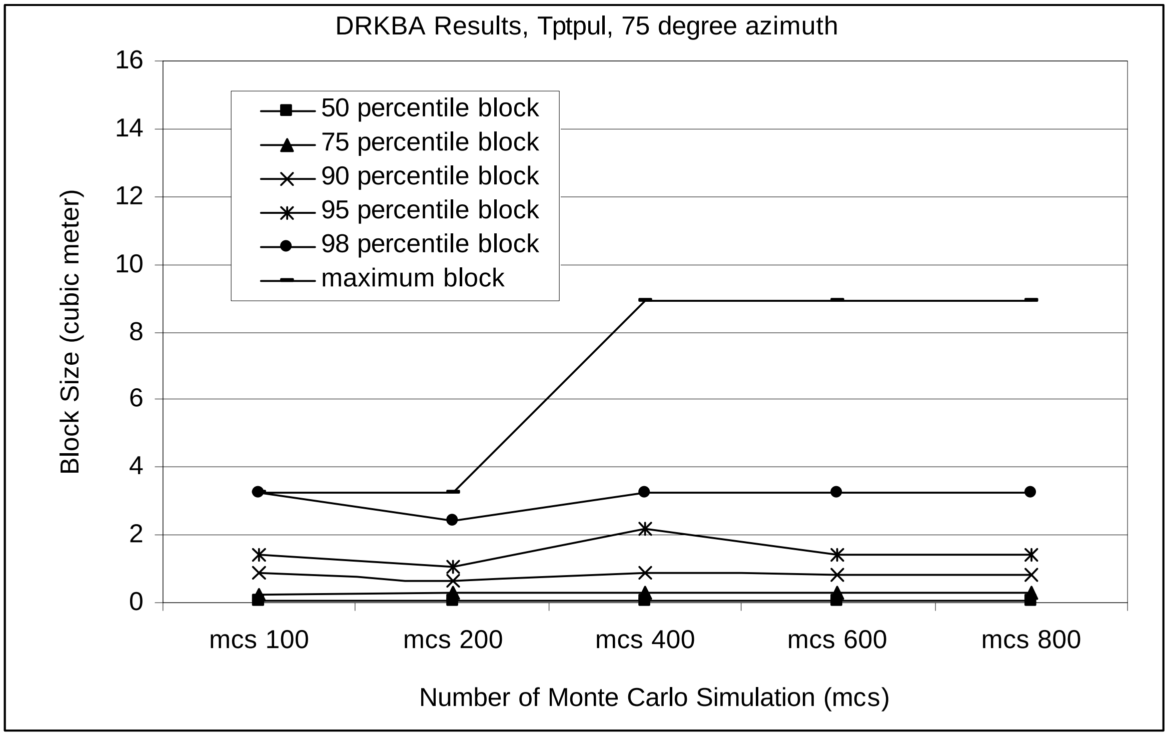


Figure 9. Predicted Maximum Block Size for Various Monte Carlo Simulations in the Tptpul Unit (Attachment I, file *mcs sensitivity study Tptpul v1.xls*)

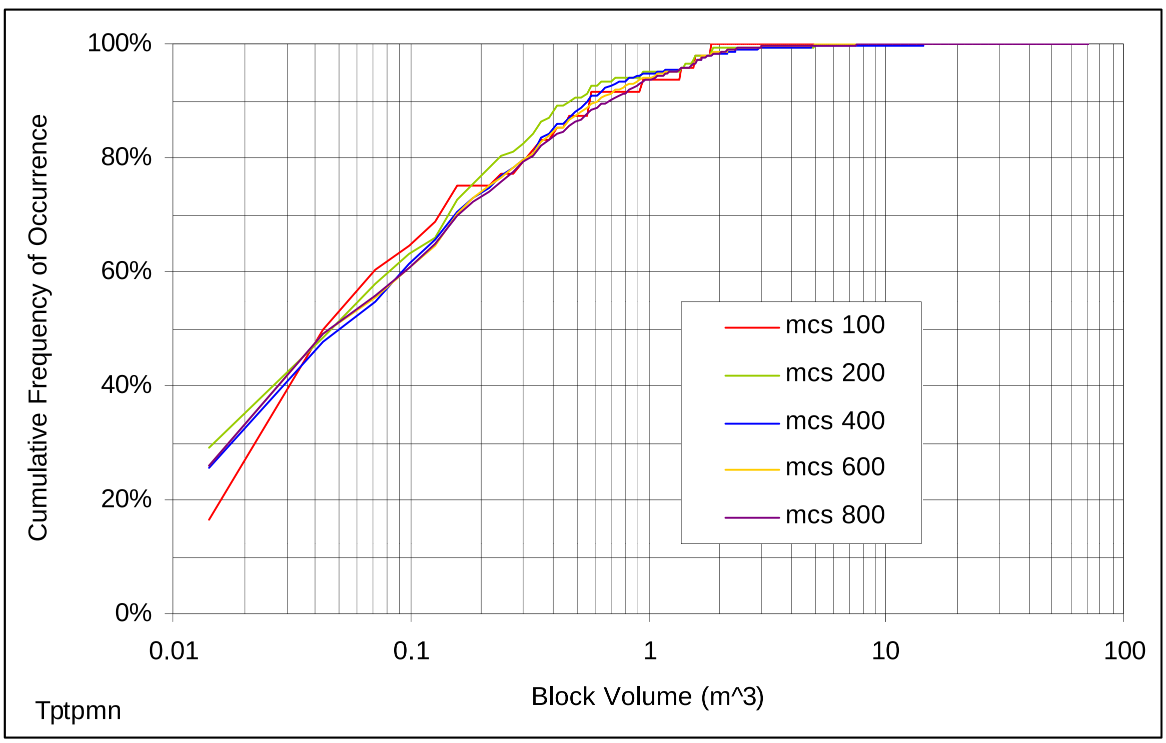


Figure 10. Block Size Distributions for Various Monte Carlo Simulations in the Tptpmn Unit (Attachment I, file *mcs sensitivity study Tptpmn v1.xls*)

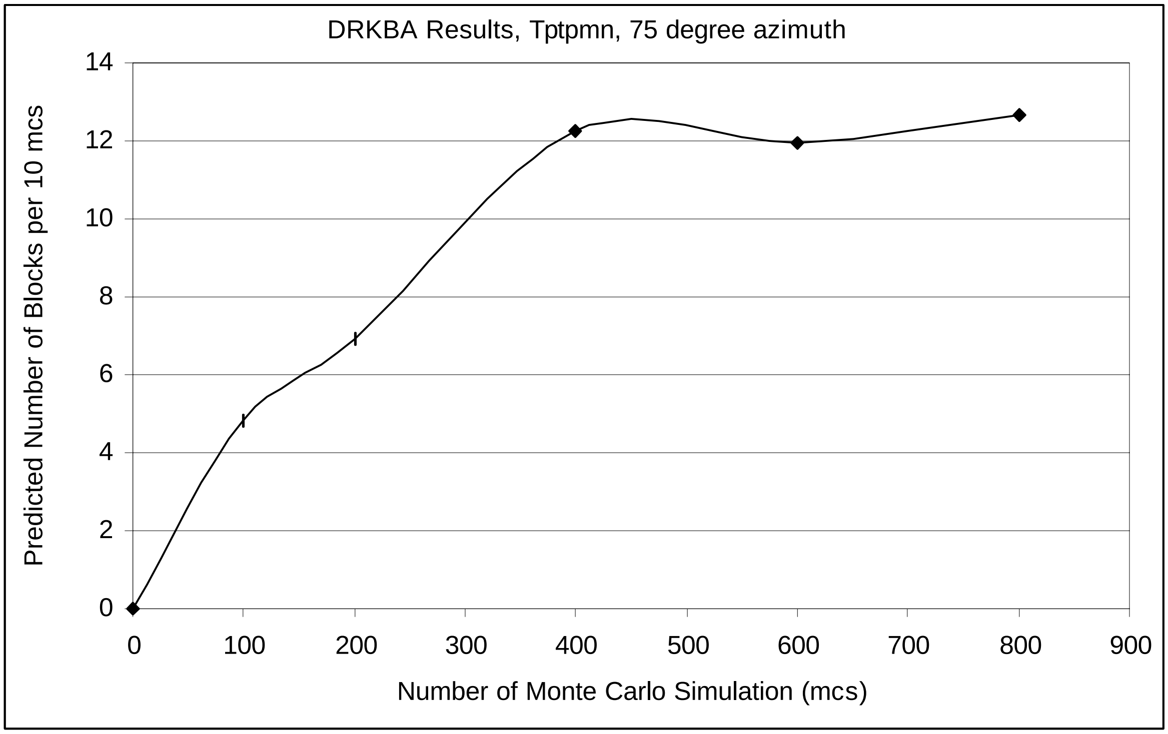


Figure 11. Predicted Number of Key Blocks for Various Monte Carlo Simulations in the Tptpmn Unit (Attachment I, file *mcs sensitivity study Tptpmn v1.xls*)

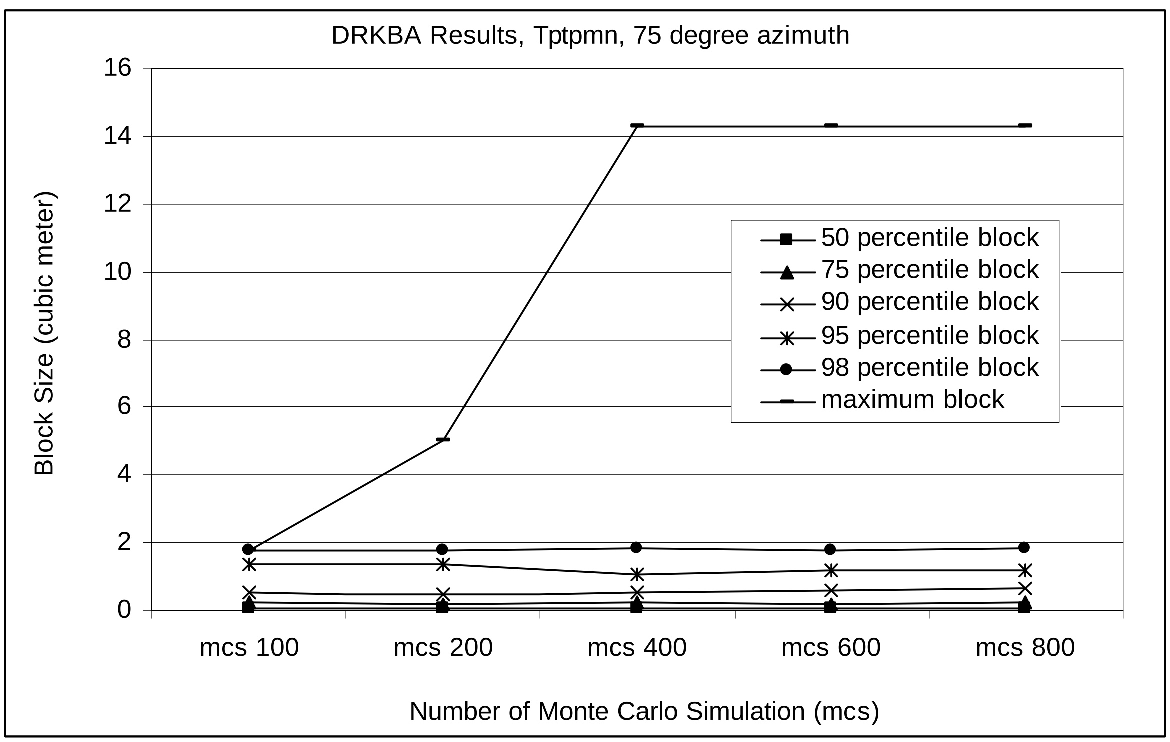


Figure 12. Predicted Maximum Block Size for Various Monte Carlo Simulations in the Tptpmn Unit (Attachment I, file *mcs sensitivity study Tptpmn v1.xls*)

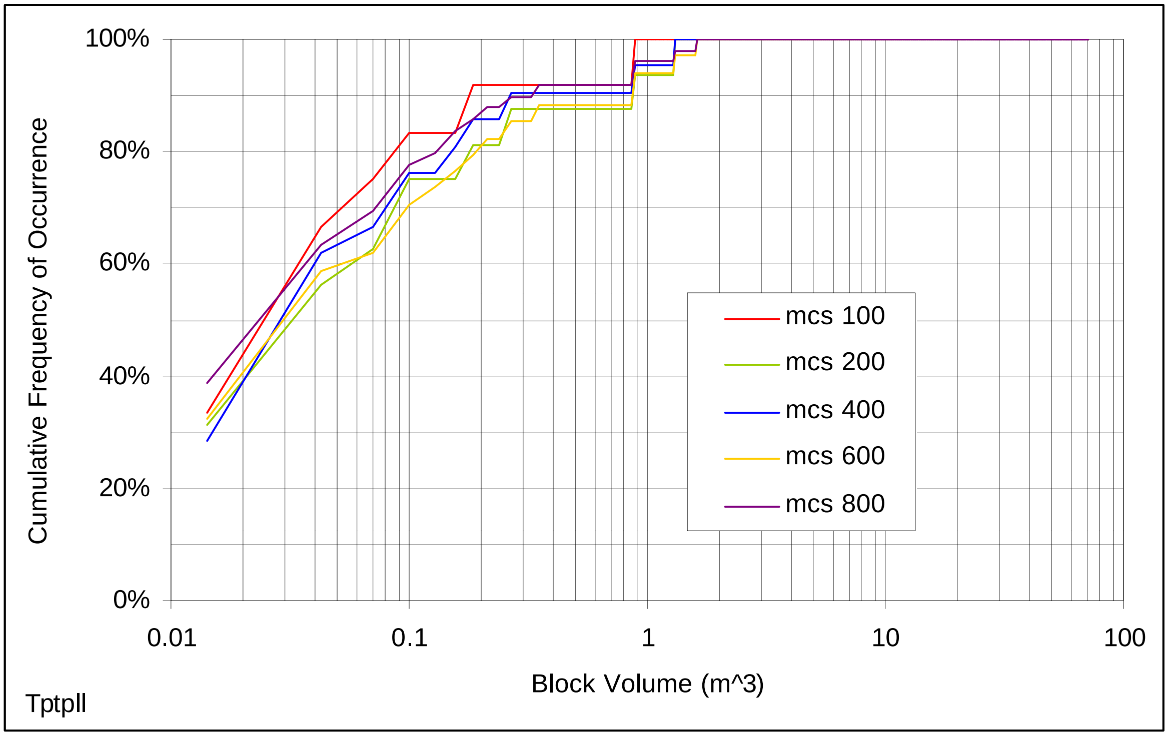


Figure 13. Block Size Distributions for Various Monte Carlo Simulations in the Tptpll Unit (Attachment I, file *mcs sensitivity study Tptpll v1.xls*)

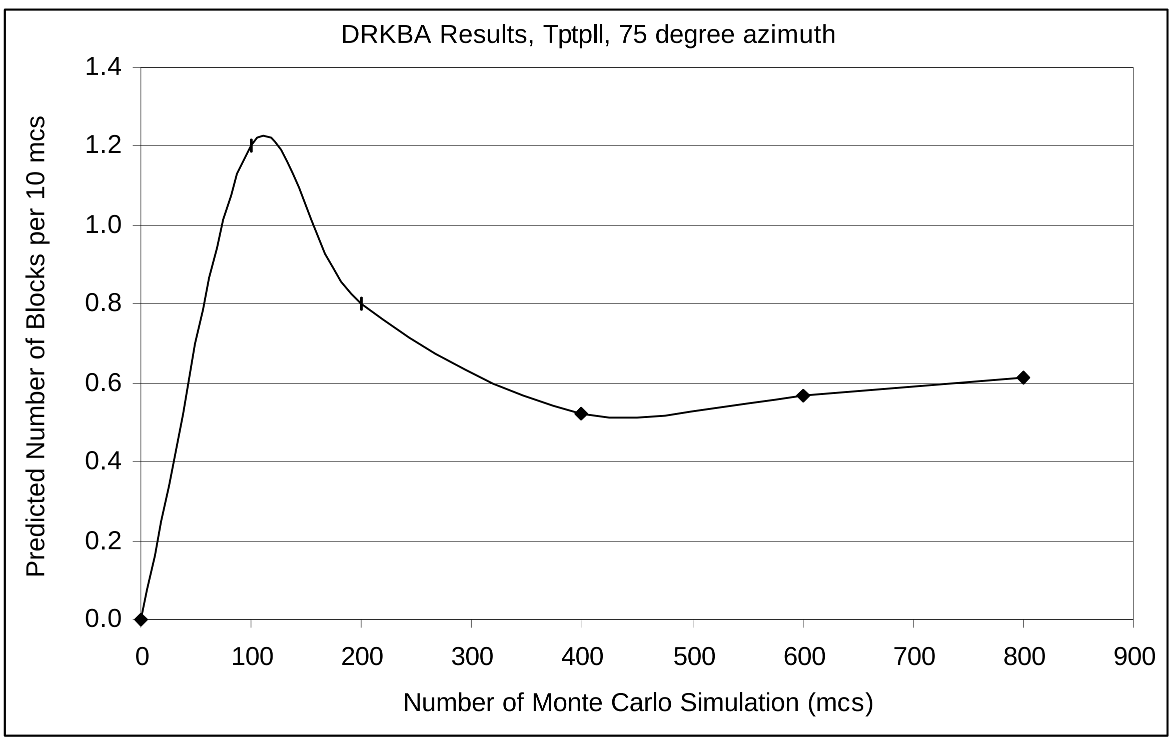


Figure 14. Predicted Number of Key Blocks for Various Monte Carlo Simulations in the Tptpll Unit (Attachment I, file *mcs sensitivity study Tptpll v1.xls*)

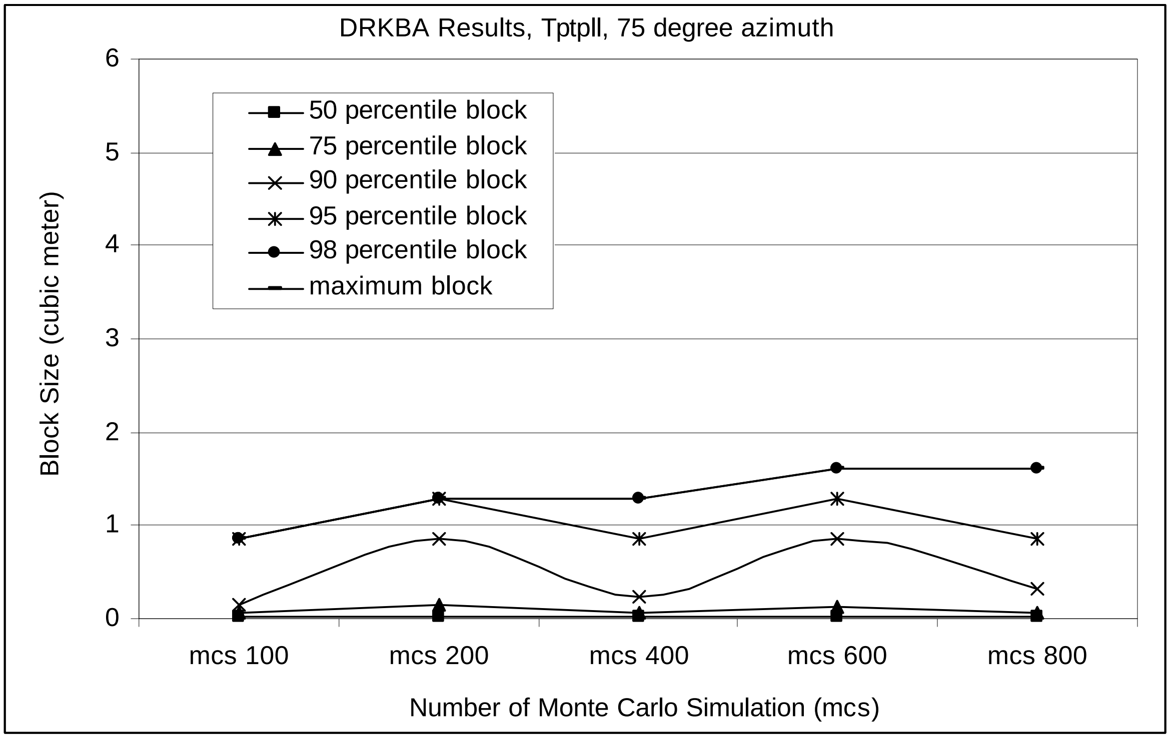


Figure 15. Predicted Maximum Block Size for Various Monte Carlo Simulations in the Tptpll Unit (Attachment I, file *mcs sensitivity study Tptpll v1.xls*)

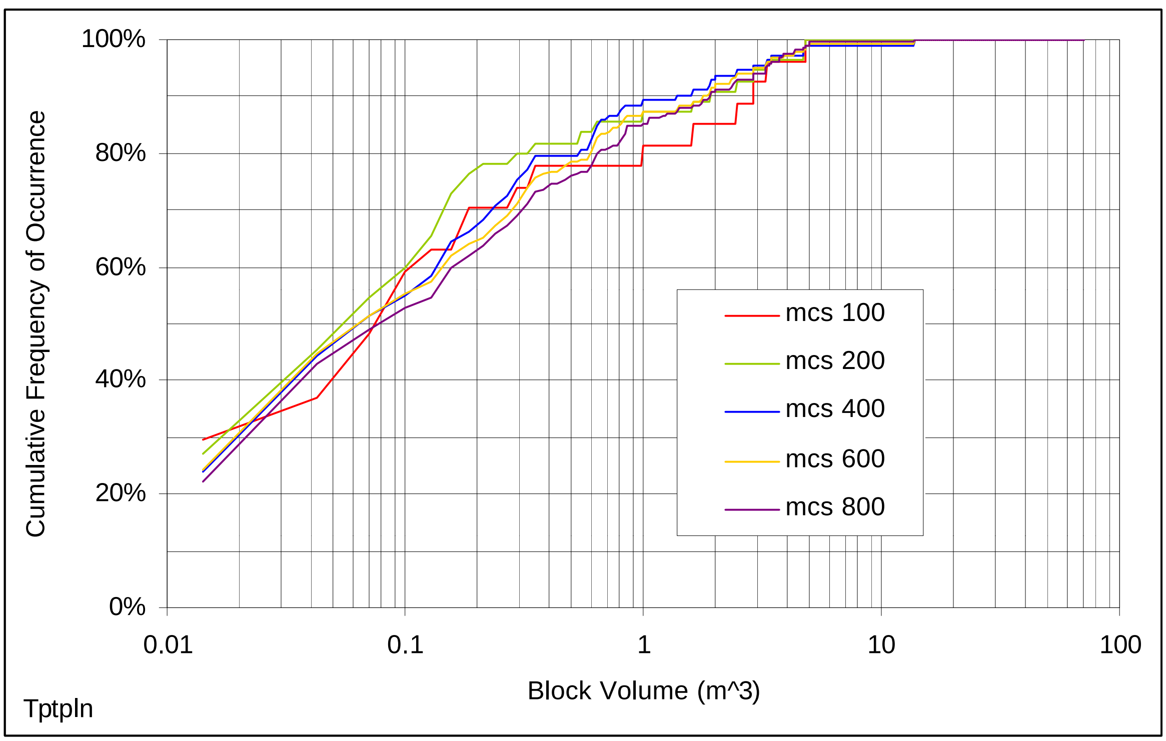


Figure 16. Block Size Distributions for Various Monte Carlo Simulations in the Tptpln Unit (Attachment I, file *mcs sensitivity study Tptpln v1.xls*)

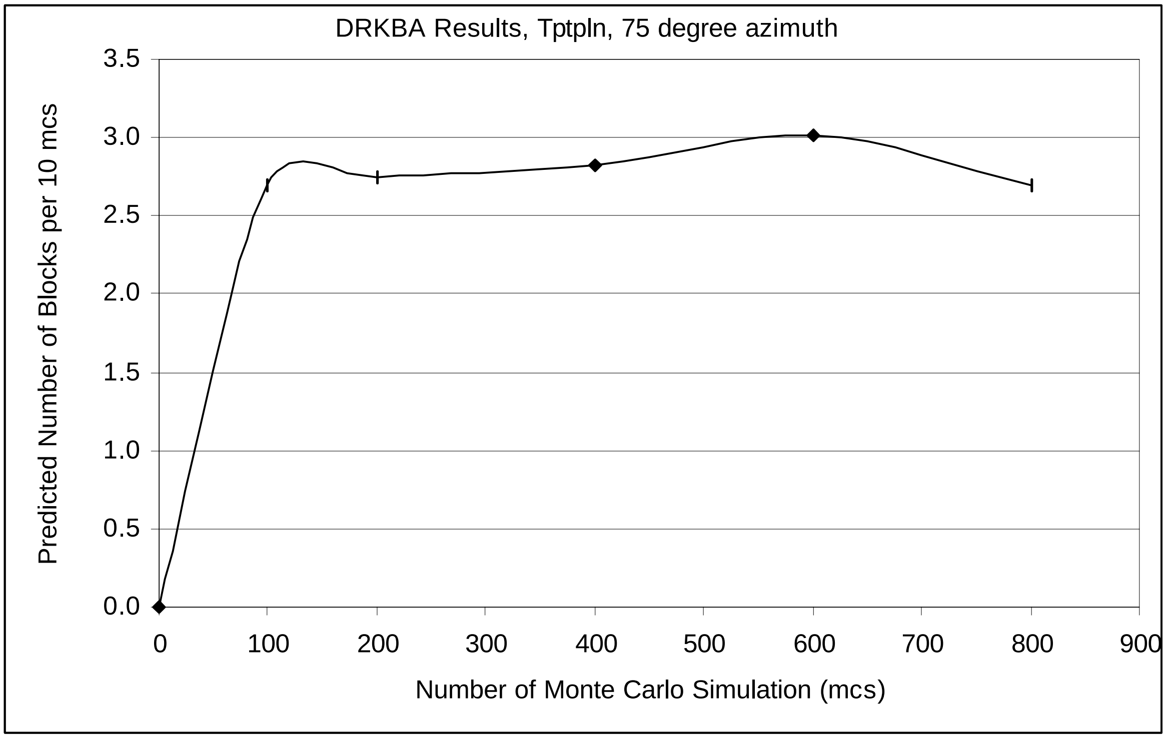


Figure 17. Predicted Number of Key Blocks for Various Monte Carlo Simulations in the Tptpln Unit (Attachment I, file *mcs sensitivity study Tptpln v1.xls*)

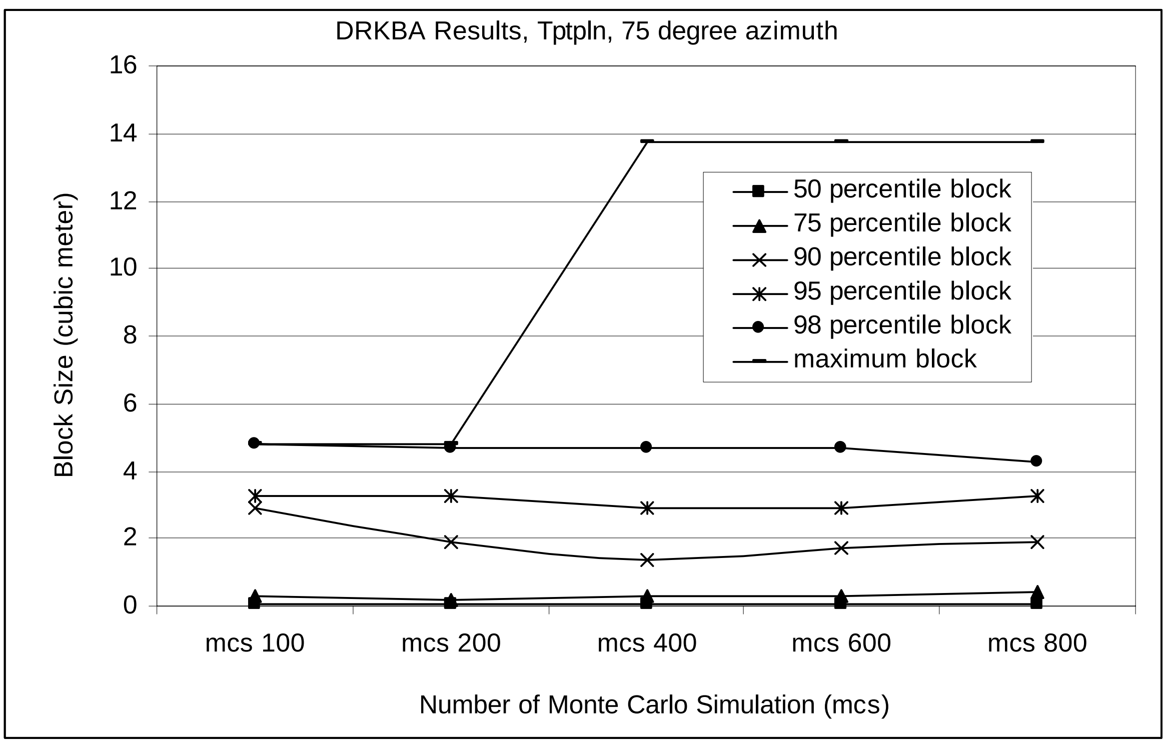


Figure 18. Predicted Maximum Block Size for Various Monte Carlo Simulations in the Tptpln Unit (Attachment I, file *mcs sensitivity study Tptpln v1.xls*)

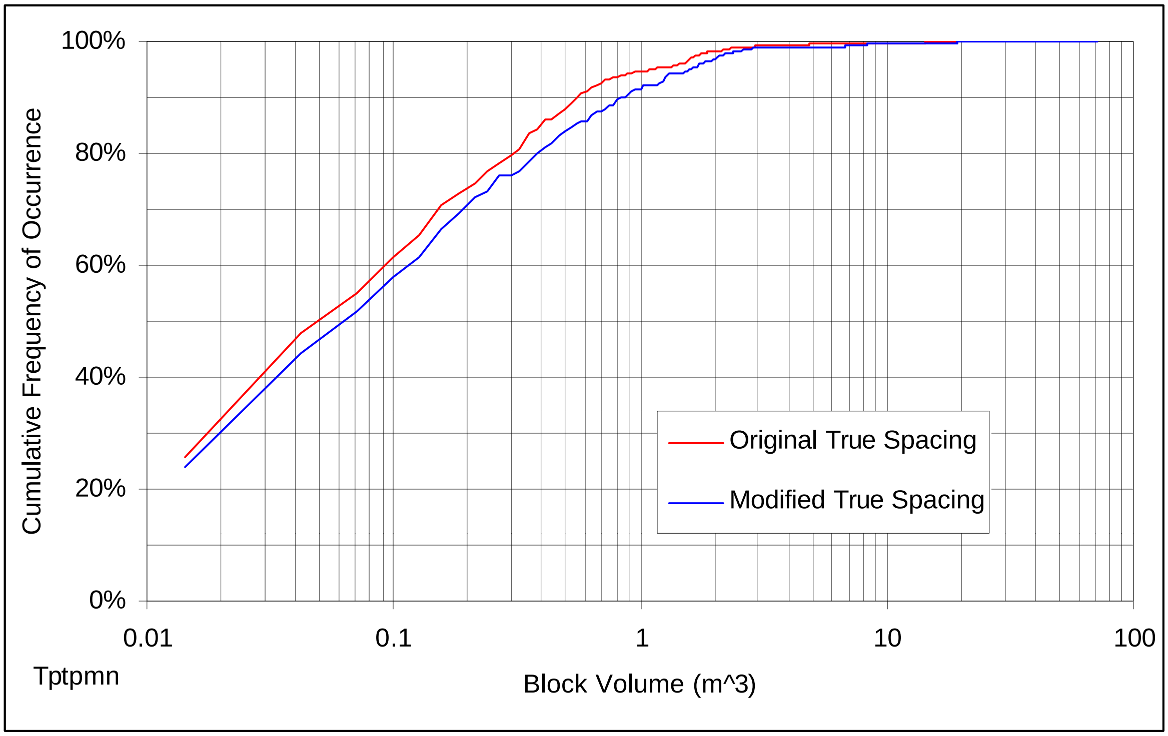


Figure 19. Cumulative Key-Block Size Distribution for Original and Modified Terzaghi Corrections of the Subhorizontal Joint Set in the Tptpmn Unit, 75°-Azimuth (Attachment I, file *tpmn 75 Terzaghi res v1.xls*)

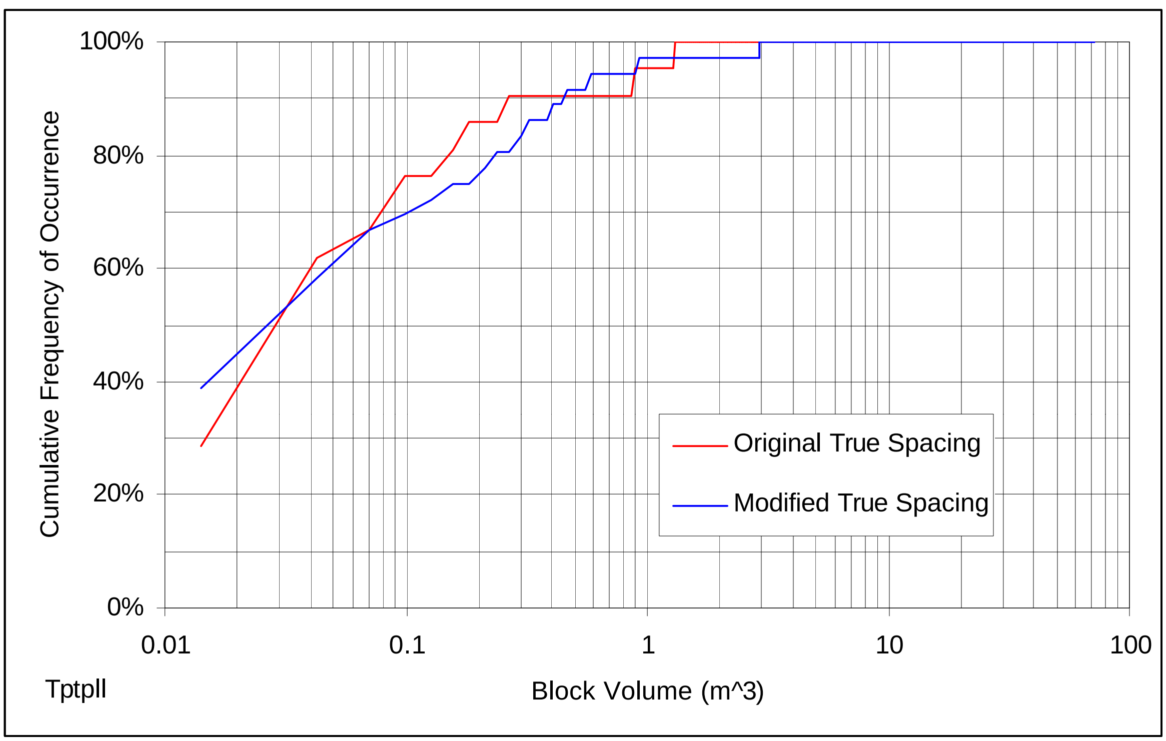


Figure 20. Cumulative Key-Block Size Distribution for Original and Modified Terzaghi Corrections of the Subhorizontal Joint Set in the Tptpll Unit, 75°-Azimuth (Attachment I, file *tpll 75 Terzaghi res v1.xls*)

Table 11. Block Volume (in cubic meters) Corresponding to Various Levels of Predicted Cumulative Frequency of Occurrence, Emplacement Drift in Tptpmn and Tptpll Units, Static Condition with Modified Terzaghi Correction (Attachment I, files *tpmn 75 Terzaghi res v1.xls* and *tpll 75 Terzaghi res v1.xls*)

Cumulative Frequency of Occurrence (%)	**Terzaghi Correction Factor**			
	Tptpmn		**Tptpll**	
	Original	**Modified**	**Original**	**Modified**
50	0.04	0.04	0.01	0.01
75	0.21	0.24	0.07	0.18
90	0.55	0.81	0.24	0.44
95	1.06	1.54	0.86	0.89
98	1.85	2.36	1.29	2.90
maximum	14.29	19.35	1.29	2.90

Table 12. Predicted Number of Key Blocks per Unit Length (km) along Emplacement Drift, Static Condition with Modified Terzaghi Correction (Attachment I, files *tpmn 75 Terzaghi res v1.xls* and *tpll 75 Terzaghi res v1.xls*)

Lithologic Unit	**Terzaghi Correction Factor**	
	Original	**Modified**
Tptpmn	50	33
Tptpll	2	4

7. REFERENCES

7.1 DOCUMENTS CITED

BSC (Bechtel SAIC Company, LLC) 2001a. *Technical Work Plan for EBS Department Modeling FY 01 Work Activities*. TWP-MGR-MD-000015 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010924.0050.

BSC 2001b. *Drift Degradation Analysis.* ANL-EBS-MD-000027 REV 01 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011029.0311.

BSC 2001c. *Subsurface Facility System Description Document*. SDD-SFS-SE-000001 REV 01 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010927.0073.

CRWMS M&O 2000a. *Software Code: DRKBA.* V3.3. PC. 10071-3.3-00.

CRWMS M&O 2000b. *Fracture Geometry Analysis for the Stratigraphic Units of the Repository Host Horizon*. ANL-EBS-GE-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000918.0286.

7.2 SOURCE DATA, LISTED BY DATA TRACKING NUMBER

MO0109RDDAAMRR.003. Results from Drift Degradation Analysis. Submittal date: 09/24/2001. Submit to RPC URN-0949

7.3 PROCEDURES

AP-3.12Q, Revision 0, ICN 4. *Calculations*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010404.0008.

AP-SI.1Q, Revision 3, ICN 2, ECN 1. *Software Management*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20011030.0598.

7.4 OUTPUT DATA, LISTED BY DATA TRACKING NUMBER

MO0110RPCRFCDD.001. Results from Supporting Rock Fall Calculation for Drift Degradation: Quantification of Uncertainties. Submittal date: 10/10/2001.

8. ATTACHMENTS

ATTACHMENT I

DRIFT DEGRADATION CALCULATION COMPUTER FILES

DRIFT DEGRADATION CALCULATION COMPUTER FILES

This attachment provides a list of computer files for the drift degradation calculation. The computer files are contained on a CD-ROM included with this attachment. The CD-ROM includes 47 folders, 239 files, with a total file size of 66.7 MB. In accordance with the technical work plan (BSC 2001a, Section 10), the properties inherent in the CD-ROM (i.e., read-only) provide adequate control to protect the data files and ensure the data are readily retrievable. Complete file information, including file names, file dates and times, and file sizes, is provided in Table I-1.

The list of computer files is separated into three main directories on the CD-ROM included in this attachment:

- *Fracture Size* — includes all computer files used in the calculation of the sensitivity of the size of the joint plane in the DRKBA rock fall model.

- *Monte Carlo Simulations* — includes all computer files used in the calculation of the sensitivity of the number of Monte Carlo simulations.

- *Terzaghi Correction* — includes all computer files used in the calculation of the sensitivity of the Terzaghi correction factor applied to the spacing of subhorizontal joints.

Each of the three main directories listed above contains two sub-directories, one for calculation files, and one for DRKBA input and output files. All calculation files were created using *Excel 97 SR-2* (see Section 4.2) and have the file name extension, *.xls*. All DRKBA input and output files (extensions *.exc*, *.mkg*, *.den*, *.prb*, *.ana*, *.bsd*, and *.kbo*) are ASCII text files and can be accessed using any suitable text editor. A brief description of each file is provided in Table I-1.

Table I-1. Drift Degradation Calculation Computer File Information

Main Directory	Sub-Directory			File Name	File Size	File Date and Time	Brief Description
Fracture Size	Calculation Files			tpll stat 75 trace length res v1.xls	5,971KB	9/20/01 10:20 AM	Rock blocks cumulative frequency of occurrence, Tptpll, fracture radius varied
				tpmn stat 75 trace length res v1.xls	5,976KB	9/20/01 10:19 AM	Rock blocks cumulative frequency of occurrence, Tptpmn, fracture radius varied
				Tptpll with various radius multiplier.xls	95KB	3/21/01 9:51 AM	Calculation of beta distribution parameters for various radius multipliers, Tptpll
				Tptpmn with various radius multiplier.xls	94KB	3/21/01 9:45 AM	Calculation of beta distribution parameters for various radius multipliers, Tptpmn
	DRKBA Inputs & Outputs	pll-stat	1p5tl	e55075.exc	1KB	12/1/98 4:42 PM	Tptpll, M = 1.5, input excavation file
				G036aa.mkg	1KB	12/23/98 3:09 PM	Tptpll, M = 1.5, input grid file
				K036aa.ana	2KB	8/2/99 2:25 PM	Tptpll, M = 1.5, input summary file
				K036AA.bsd	554KB	3/21/01 1:54 PM	Tptpll, M = 1.5, output file for block size distribution
				K036AA.kbo	2KB	3/21/01 1:54 PM	Tptpll, M = 1.5, output file for key block information
				TpllAA.den	1KB	12/9/98 2:39 PM	Tptpll, M = 1.5, input density file
				Tpllaa.prb	2KB	3/21/01 9:54 AM	Tptpll, M = 1.5, input joint data file
			1tl	e55075.exc	1KB	12/1/98 4:42 PM	Tptpll, M = 1.0, input excavation file
				G036aa.mkg	1KB	12/23/98 3:09 PM	Tptpll, M = 1.0, input grid file
				K036aa.ana	2KB	8/2/99 2:25 PM	Tptpll, M = 1.0, input summary file
				K036AA.bsd	554KB	9/28/00 5:31 AM	Tptpll, M = 1.0, output file for block size distribution
				K036AA.kbo	1KB	9/28/00 5:31 AM	Tptpll, M = 1.0, output file for key block information
				TpllAA.den	1KB	12/9/98 2:39 PM	Tptpll, M = 1.0, input density file
				Tpllaa.prb	2KB	9/27/00 3:41 PM	Tptpll, M = 1.0, input joint data file
			2p5tl	e55075.exc	1KB	12/1/98 4:42 PM	Tptpll, M = 2.5, input excavation file
				G036aa.mkg	1KB	12/23/98 3:09 PM	Tptpll, M = 2.5, input grid file
				K036aa.ana	2KB	8/2/99 2:25 PM	Tptpll, M = 2.5, input summary file
				K036AA.bsd	554KB	3/21/01 3:31 PM	Tptpll, M = 2.5, output file for block size distribution

Table I-1. Drift Degradation Calculation Computer File Information (Continued)

Main Directory	Sub-Directory			File Name	File Size	File Date and Time	Brief Description
Fracture Size	DRKBA Inputs & Outputs	pll-stat	2p5tl	K036AA.kbo	5KB	3/21/01 3:31 PM	Tptpll, M = 2.5, output file for key block information
				TpllAA.den	1KB	12/9/98 2:39 PM	Tptpll, M = 2.5, input density file
				Tpllaa.prb	2KB	3/21/01 9:56 AM	Tptpll, M = 2.5, input joint data file
			2tl	e55075.exc	1KB	12/1/98 4:42 PM	Tptpll, M = 2.0, input excavation file
				G036aa.mkg	1KB	12/23/98 3:09 PM	Tptpll, M = 2.0, input grid file
				K036aa.ana	2KB	8/2/99 2:25 PM	Tptpll, M = 2.0, input summary file
				K036AA.bsd	554KB	8/21/99 8:50 AM	Tptpll, M = 2.0, output file for block size distribution
				K036AA.kbo	3KB	8/21/99 8:50 AM	Tptpll, M = 2.0, output file for key block information
				TpllAA.den	1KB	12/9/98 2:39 PM	Tptpll, M = 2.0, input density file
				Tpllaa.prb	2KB	8/19/99 5:42 PM	Tptpll, M = 2.0, input joint data file
			3tl	e55075.exc	1KB	12/1/98 4:42 PM	Tptpll, M = 3.0, input excavation file
				G036aa.mkg	1KB	12/23/98 3:09 PM	Tptpll, M = 3.0, input grid file
				K036aa.ana	2KB	8/2/99 2:25 PM	Tptpll, M = 3.0, input summary file
				K036AA.bsd	554KB	9/29/00 4:47 AM	Tptpll, M = 3.0, output file for block size distribution
				K036AA.kbo	6KB	9/29/00 4:47 AM	Tptpll, M = 3.0, output file for key block information
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				Tpllaa.prb	2KB	9/27/00 3:42 PM	Tptpll, M = 3.0, input joint data file
		pmn-stat	1p5tl	e55075.exc	1KB	12/1/98 4:42 PM	Tptpmn, M = 1.5, input excavation file
				G022aa.mkg	1KB	12/23/98 3:06 PM	Tptpmn, M = 1.5, input grid file
				K022aa.ana	2KB	3/21/01 10:13 AM	Tptpmn, M = 1.5, input summary file
				K022AA.bsd	554KB	3/21/01 8:10 PM	Tptpmn, M = 1.5, output file for block size distribution
				K022AA.kbo	11KB	3/21/01 8:05 PM	Tptpmn, M = 1.5, output file for key block information
				TpmnAA.den	1KB	12/9/98 2:39 PM	Tptpmn, M = 1.5, input density file
				Tpmnaa.prb	2KB	3/21/01 10:04 AM	Tptpmn, M = 1.5, input joint data file

Table I-1. Drift Degradation Calculation Computer File Information (Continued)

Main Directory	Sub-Directory			File Name	File Size	File Date and Time	Brief Description
Fracture Size	DRKBA Inputs & Outputs	pmn-stat	1tl	e55075.exc	1KB	12/1/98 4:42 PM	Tptpmn, M = 1.0, input excavation file
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				K022aa.ana	2KB	3/21/01 10:13 AM	Tptpmn, M = 1.0, input summary file
				K022AA.bsd	554KB	3/22/01 5:46 AM	Tptpmn, M = 1.0, output file for block size distribution
				K022AA.kbo	2KB	3/22/01 5:32 AM	Tptpmn, M = 1.0, output file for key block information
				TpmnAA.den	1KB	12/9/98 2:39 PM	Tptpmn, M = 1.0, input density file
				Tpmnaa.prb	2KB	9/27/00 3:09 PM	Tptpmn, M = 1.0, input joint data file
			2p5tl	e55075.exc	1KB	12/1/98 4:42 PM	Tptpmn, M = 2.5, input excavation file
				G022aa.mkg	1KB	12/23/98 3:06 PM	Tptpmn, M = 2.5, input grid file
				K022aa.ana	2KB	3/21/01 10:14 AM	Tptpmn, M = 2.5, input summary file
				K022AA.bsd	554KB	3/22/01 12:59 AM	Tptpmn, M = 2.5, output file for block size distribution
				K022AA.kbo	139KB	3/22/01 12:57 AM	Tptpmn, M = 2.5, output file for key block information
				TpmnAA.den	1KB	12/9/98 2:39 PM	Tptpmn, M = 2.5, input density file
				Tpmnaa.prb	2KB	3/21/01 10:05 AM	Tptpmn, M = 2.5, input joint data file
			2tl	e55075.exc	1KB	12/1/98 5:42 PM	Tptpmn, M = 2.0, input excavation file
				G022aa.mkg	1KB	12/23/98 4:06 PM	Tptpmn, M = 2.0, input grid file
				K022aa.ana	2KB	9/15/99 9:31 AM	Tptpmn, M = 2.0, input summary file
				K022AA.bsd	554KB	3/14/01 9:00 PM	Tptpmn, M = 2.0, output file for block size distribution
				K022AA.kbo	47KB	3/14/01 8:56 PM	Tptpmn, M = 2.0, output file for key block information
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			3tl	e55075.exc	1KB	12/1/98 4:42 PM	Tptpmn, M = 3.0, input excavation file
				G022aa.mkg	1KB	12/23/98 3:06 PM	Tptpmn, M = 3.0, input grid file
				K022aa.ana	2KB	3/21/01 10:14 AM	Tptpmn, M = 3.0, input summary file
				K022AA.bsd	554KB	3/22/01 10:49 AM	Tptpmn, M = 3.0, output file for block size distribution

Table I-1. Drift Degradation Calculation Computer File Information (Continued)

Main Directory	Sub-Directory			File Name	File Size	File Date and Time	Brief Description
Fracture Size	DRKBA Inputs & Outputs	pmn-stat	3tl	K022AA.kbo	243KB	3/22/01 10:49 AM	Tptpmn, M = 3.0, output file for key block information
				TpmnAA.den	1KB	12/9/98 2:39 PM	Tptpmn, M = 3.0, input density file
				Tpmnaa.prb	2KB	9/27/00 3:10 PM	Tptpmn, M = 3.0, input joint data file
Monte Carlo Simulation	Calculation Files			mcs sensitivity study Tptpll v1.xls	5,933KB	9/20/01 10:25 AM	Rock blocks cumulative frequency of occurrence, Tptpul, Monte Carlo simulations varied
				mcs sensitivity study Tptpln v1.xls	6,314KB	9/20/01 10:26 AM	Rock blocks cumulative frequency of occurrence, Tptpmn, Monte Carlo simulations varied
				mcs sensitivity study Tptpmn v1.xls	5,958KB	9/20/01 10:24 AM	Rock blocks cumulative frequency of occurrence, Tptpll, Monte Carlo simulations varied
				mcs sensitivity study Tptpul v1.xls	5,931KB	9/20/01 10:23 AM	Rock blocks cumulative frequency of occurrence, Tptpln, Monte Carlo simulations varied
	DRKBA Inputs & Outputs	k008aa	mcs100	e55075.exc	1KB	12/1/98 4:42 PM	Tptpul, 100 simulations, input excavation file
				G008aa.mkg	1KB	12/23/98 3:01 PM	Tptpul, 100 simulations, input grid file
				K008aa.ana	2KB	3/12/01 6:11 PM	Tptpul, 100 simulations, input summary file
				K008AA.bsd	552KB	3/12/01 7:06 PM	Tptpul, 100 simulations, output file for block size distribution
				K008AA.kbo	5KB	9/20/01 4:19 PM	Tptpul, 100 simulations, output file for key block information
				TpulAA.den	1KB	12/9/98 2:39 PM	Tptpul, 100 simulations, input density file
				Tpulaa.prb	2KB	9/3/99 8:59 AM	Tptpul, 100 simulations, input joint data file
			mcs200	e55075.exc	1KB	12/1/98 4:42 PM	Tptpul, 200 simulations, input excavation file
				G008aa.mkg	1KB	12/23/98 3:01 PM	Tptpul, 200 simulations, input grid file
				K008aa.ana	2KB	3/12/01 6:11 PM	Tptpul, 200 simulations, input summary file
				K008AA.bsd	553KB	3/12/01 8:18 PM	Tptpul, 200 simulations, output file for block size distribution
				K008AA.kbo	10KB	3/12/01 8:17 PM	Tptpul, 200 simulations, output file for key block information

Table I-1. Drift Degradation Calculation Computer File Information (Continued)

Main Directory	Sub-Directory			File Name	File Size	File Date and Time	Brief Description
Monte Carlo Simulation	DRKBA Inputs & Outputs	k008aa	mcs200	TpulAA.den	1KB	12/9/98 2:39 PM	Tptpul, 200 simulations, input density file
				Tpulaa.prb	2KB	9/3/99 8:59 AM	Tptpul, 200 simulations, input joint data file
			mcs400	e55075.exc	1KB	12/1/98 4:42 PM	Tptpul, 400 simulations, input excavation file
				G008aa.mkg	1KB	12/23/98 3:01 PM	Tptpul, 400 simulations, input grid file
				K008aa.ana	2KB	9/3/99 9:25 AM	Tptpul, 400 simulations, input summary file
				K008AA.bsd	554KB	9/5/99 3:05 AM	Tptpul, 400 simulations, output file for block size distribution
				K008AA.kbo	15KB	9/5/99 3:05 AM	Tptpul, 400 simulations, output file for key block information
				TpulAA.den	1KB	12/9/98 2:39 PM	Tptpul, 400 simulations, input density file
				Tpulaa.prb	2KB	9/3/99 8:59 AM	Tptpul, 400 simulations, input joint data file
			mcs600	e55075.exc	1KB	12/1/98 4:42 PM	Tptpul, 600 simulations, input excavation file
				G008aa.mkg	1KB	12/23/98 3:01 PM	Tptpul, 600 simulations, input grid file
				K008aa.ana	2KB	3/12/01 6:11 PM	Tptpul, 600 simulations, input summary file
				K008AA.bsd	555KB	3/12/01 11:49 PM	Tptpul, 600 simulations, output file for block size distribution
				K008AA.kbo	21KB	3/12/01 11:49 PM	Tptpul, 600 simulations, output file for key block information
				TpulAA.den	1KB	12/9/98 2:39 PM	Tptpul, 600 simulations, input density file
				Tpulaa.prb	2KB	9/3/99 8:59 AM	Tptpul, 600 simulations, input joint data file
			mcs800	e55075.exc	1KB	12/1/98 4:42 PM	Tptpul, 800 simulations, input excavation file
				G008aa.mkg	1KB	12/23/98 3:01 PM	Tptpul, 800 simulations, input grid file
				K008aa.ana	2KB	3/12/01 6:11 PM	Tptpul, 800 simulations, input summary file
				K008AA.bsd	557KB	3/13/01 4:32 AM	Tptpul, 800 simulations, output file for block size distribution
				K008AA.kbo	27KB	3/13/01 4:31 AM	Tptpul, 800 simulations, output file for key block information
				TpulAA.den	1KB	12/9/98 2:39 PM	Tptpul, 800 simulations, input density file
				Tpulaa.prb	2KB	9/3/99 8:59 AM	Tptpul, 800 simulations, input joint data file
		k022aa	mcs100	e55075.exc	1KB	12/1/98 5:42 PM	Tptpmn, 100 simulations, input excavation file
				G022aa.mkg	1KB	12/23/98 4:06 PM	Tptpmn, 100 simulations, input grid file
				K022aa.ana	2KB	9/14/99 10:04 AM	Tptpmn, 100 simulations, input summary file

Table I-1. Drift Degradation Calculation Computer File Information (Continued)

Main Directory	Sub-Directory			File Name	File Size	File Date and Time	Brief Description
Monte Carlo Simulation	DRKBA Inputs & Outputs	k022aa	mcs100	K022AA.bsd	552KB	9/14/99 1:19 PM	Tptpmn, 100 simulations, output file for block size distribution
				K022AA.kbo	5KB	9/14/99 1:19 PM	Tptpmn, 100 simulations, output file for key block information
				TpmnAA.den	1KB	12/9/98 3:39 PM	Tptpmn, 100 simulations, input density file
				Tpmnaa.prb	2KB	8/31/99 6:17 PM	Tptpmn, 100 simulations, input joint data file
			mcs200	e55075.exc	1KB	12/1/98 4:42 PM	Tptpmn, 200 simulations, input excavation file
				G022aa.mkg	1KB	12/23/98 3:06 PM	Tptpmn, 200 simulations, input grid file
				K022aa.ana	2KB	9/2/99 8:45 AM	Tptpmn, 200 simulations, input summary file
				K022AA.bsd	553KB	9/3/99 12:05 AM	Tptpmn, 200 simulations, output file for block size distribution
				K022AA.kbo	14KB	9/3/99 12:05 AM	Tptpmn, 200 simulations, output file for key block information
				TpmnAA.den	1KB	12/9/98 2:39 PM	Tptpmn, 200 simulations, input density file
				Tpmnaa.prb	2KB	8/31/99 5:17 PM	Tptpmn, 200 simulations, input joint data file
			mcs400	e55075.exc	1KB	12/1/98 5:42 PM	Tptpmn, 400 simulations, input excavation file
				G022aa.mkg	1KB	12/23/98 4:06 PM	Tptpmn, 400 simulations, input grid file
				K022aa.ana	2KB	9/15/99 9:31 AM	Tptpmn, 400 simulations, input summary file
				K022AA.bsd	554KB	3/14/01 9:00 PM	Tptpmn, 400 simulations, output file for block size distribution
				K022AA.kbo	47KB	3/14/01 8:56 PM	Tptpmn, 400 simulations, output file for key block information
				TpmnAA.den	1KB	12/9/98 3:39 PM	Tptpmn, 400 simulations, input density file
				Tpmnaa.prb	2KB	8/31/99 6:17 PM	Tptpmn, 400 simulations, input joint data file
			mcs600	e55075.exc	1KB	12/1/98 4:42 PM	Tptpmn, 600 simulations, input excavation file
				G022aa.mkg	1KB	12/23/98 3:06 PM	Tptpmn, 600 simulations, input grid file
				K022aa.ana	2KB	3/12/01 6:12 PM	Tptpmn, 600 simulations, input summary file
				K022AA.bsd	555KB	3/13/01 11:33 AM	Tptpmn, 600 simulations, output file for block size distribution
				K022AA.kbo	68KB	3/13/01 11:33 AM	Tptpmn, 600 simulations, output file for key block information
				TpmnAA.den	1KB	12/9/98 2:39 PM	Tptpmn, 600 simulations, input density file
				Tpmnaa.prb	2KB	8/31/99 5:17 PM	Tptpmn, 600 simulations, input joint data file

Table I-1. Drift Degradation Calculation Computer File Information (Continued)

Main Directory	Sub-Directory			File Name	File Size	File Date and Time	Brief Description
Monte Carlo Simulation	DRKBA Inputs & Outputs	k022aa	mcs800	e55075.exc	1KB	12/1/98 4:42 PM	Tptpmn, 800 simulations, input excavation file
				G022aa.mkg	1KB	12/23/98 3:06 PM	Tptpmn, 800 simulations, input grid file
				K022aa.ana	2KB	3/12/01 6:13 PM	Tptpmn, 800 simulations, input summary file
				K022AA.bsd	557KB	3/13/01 8:52 AM	Tptpmn, 800 simulations, output file for block size distribution
				K022AA.kbo	96KB	3/13/01 8:47 AM	Tptpmn, 800 simulations, output file for key block information
				TpmnAA.den	1KB	12/9/98 2:39 PM	Tptpmn, 800 simulations, input density file
				Tpmnaa.prb	2KB	8/31/99 5:17 PM	Tptpmn, 800 simulations, input joint data file
		k036aa	mcs100	e55075.exc	1KB	12/1/98 4:42 PM	Tptpll, 100 simulations, input excavation file
				G036aa.mkg	1KB	12/23/98 3:09 PM	Tptpll, 100 simulations, input grid file
				K036aa.ana	2KB	3/12/01 6:13 PM	Tptpll, 100 simulations, input summary file
				K036AA.bsd	552KB	3/13/01 9:17 PM	Tptpll, 100 simulations, output file for block size distribution
				K036AA.kbo	2KB	3/13/01 9:13 PM	Tptpll, 100 simulations, output file for key block information
				TpllAA.den	1KB	12/9/98 2:39 PM	Tptpll, 100 simulations, input density file
				Tpllaa.prb	2KB	8/19/99 5:42 PM	Tptpll, 100 simulations, input joint data file
			mcs200	e55075.exc	1KB	12/1/98 4:42 PM	Tptpll, 200 simulations, input excavation file
				G036aa.mkg	1KB	12/23/98 3:09 PM	Tptpll, 200 simulations, input grid file
				K036aa.ana	2KB	3/12/01 6:13 PM	Tptpll, 200 simulations, input summary file
				K036AA.bsd	553KB	3/13/01 10:08 PM	Tptpll, 200 simulations, output file for block size distribution
				K036AA.kbo	2KB	3/13/01 9:57 PM	Tptpll, 200 simulations, output file for key block information
				TpllAA.den	1KB	12/9/98 2:39 PM	Tptpll, 200 simulations, input density file
				Tpllaa.prb	2KB	8/19/99 5:42 PM	Tptpll, 200 simulations, input joint data file
			mcs400	e55075.exc	1KB	12/1/98 4:42 PM	Tptpll, 400 simulations, input excavation file
				G036aa.mkg	1KB	12/23/98 3:09 PM	Tptpll, 400 simulations, input grid file
				K036aa.ana	2KB	8/2/99 2:25 PM	Tptpll, 400 simulations, input summary file
				K036AA.bsd	554KB	8/21/99 8:50 AM	Tptpll, 400 simulations, output file for block size distribution

Table I-1. Drift Degradation Calculation Computer File Information (Continued)

Main Directory	Sub-Directory			File Name	File Size	File Date and Time	Brief Description
Monte Carlo Simulation	DRKBA Inputs & Outputs	k036aa	mcs400	K036AA.kbo	3KB	8/21/99 8:50 AM	Tptpll, 400 simulations, output file for key block information
				TpllAA.den	1KB	12/9/98 2:39 PM	Tptpll, 400 simulations, input density file
				Tpllaa.prb	2KB	8/19/99 5:42 PM	Tptpll, 400 simulations, input joint data file
			mcs600	e55075.exc	1KB	12/1/98 4:42 PM	Tptpll, 600 simulations, input excavation file
				G036aa.mkg	1KB	12/23/98 3:09 PM	Tptpll, 600 simulations, input grid file
				K036aa.ana	2KB	3/12/01 6:14 PM	Tptpll, 600 simulations, input summary file
				K036AA.bsd	555KB	3/14/01 12:40 AM	Tptpll, 600 simulations, output file for block size distribution
				K036AA.kbo	4KB	3/14/01 12:37 AM	Tptpll, 600 simulations, output file for key block information
				TpllAA.den	1KB	12/9/98 2:39 PM	Tptpll, 600 simulations, input density file
				Tpllaa.prb	2KB	8/19/99 5:42 PM	Tptpll, 600 simulations, input joint data file
			mcs800	e55075.exc	1KB	12/1/98 4:42 PM	Tptpll, 800 simulations, input excavation file
				G036aa.mkg	1KB	12/23/98 3:09 PM	Tptpll, 800 simulations, input grid file
				K036aa.ana	2KB	3/12/01 6:14 PM	Tptpll, 800 simulations, input summary file
				K036AA.bsd	557KB	3/14/01 4:03 AM	Tptpll, 800 simulations, output file for block size distribution
				K036AA.kbo	5KB	3/14/01 4:02 AM	Tptpll, 800 simulations, output file for key block information
				TpllAA.den	1KB	12/9/98 2:39 PM	Tptpll, 800 simulations, input density file
				Tpllaa.prb	2KB	8/19/99 5:42 PM	Tptpll, 800 simulations, input joint data file
		k050aa	mcs100	e55075.exc	1KB	12/1/98 4:42 PM	Tptpln, 100 simulations, input excavation file
				G050aa.mkg	1KB	12/23/98 3:13 PM	Tptpln, 100 simulations, input grid file
				K050aa.ana	2KB	3/12/01 6:14 PM	Tptpln, 100 simulations, input summary file
				K050AA.bsd	552KB	3/14/01 4:40 AM	Tptpln, 100 simulations, output file for block size distribution
				K050AA.kbo	3KB	3/14/01 4:37 AM	Tptpln, 100 simulations, output file for key block information
				TplnAA.den	1KB	12/1/98 4:36 PM	Tptpln, 100 simulations, input density file
				Tplnaa.prb	2KB	8/17/00 8:30 AM	Tptpln, 100 simulations, input joint data file
			mcs200	e55075.exc	1KB	12/1/98 4:42 PM	Tptpln, 200 simulations, input excavation file
				G050aa.mkg	1KB	12/23/98 3:13 PM	Tptpln, 200 simulations, input grid file

Table I-1. Drift Degradation Calculation Computer File Information (Continued)

Main Directory	Sub-Directory			File Name	File Size	File Date and Time	Brief Description
Monte Carlo Simulation	DRKBA Inputs & Outputs	k050aa	mcs200	K050aa.ana	2KB	3/12/01 6:15 PM	Tptpln, 200 simulations, input summary file
				K050AA.bsd	553KB	3/14/01 5:55 AM	Tptpln, 200 simulations, output file for block size distribution
				K050AA.kbo	6KB	3/14/01 5:54 AM	Tptpln, 200 simulations, output file for key block information
				TplnAA.den	1KB	12/1/98 4:36 PM	Tptpln, 200 simulations, input density file
				Tplnaa.prb	2KB	8/17/00 8:30 AM	Tptpln, 200 simulations, input joint data file
			mcs400	e55075.exc	1KB	12/1/98 4:42 PM	Tptpln, 400 simulations, input excavation file
				G050aa.mkg	1KB	12/23/98 3:13 PM	Tptpln, 400 simulations, input grid file
				K050aa.ana	2KB	9/10/99 1:59 PM	Tptpln, 400 simulations, input summary file
				K050AA.bsd	554KB	8/23/00 7:32 PM	Tptpln, 400 simulations, output file for block size distribution
				K050AA.kbo	11KB	8/23/00 7:32 PM	Tptpln, 400 simulations, output file for key block information
				TplnAA.den	1KB	12/1/98 4:36 PM	Tptpln, 400 simulations, input density file
				Tplnaa.prb	2KB	8/17/00 8:30 AM	Tptpln, 400 simulations, input joint data file
			mcs600	e55075.exc	1KB	12/1/98 4:42 PM	Tptpln, 600 simulations, input excavation file
				G050aa.mkg	1KB	12/23/98 3:13 PM	Tptpln, 600 simulations, input grid file
				K050aa.ana	2KB	3/12/01 6:15 PM	Tptpln, 600 simulations, input summary file
				K050AA.bsd	555KB	3/14/01 9:34 AM	Tptpln, 600 simulations, output file for block size distribution
				K050AA.kbo	18KB	3/14/01 9:31 AM	Tptpln, 600 simulations, output file for key block information
				TplnAA.den	1KB	12/1/98 4:36 PM	Tptpln, 600 simulations, input density file
				Tplnaa.prb	2KB	8/17/00 8:30 AM	Tptpln, 600 simulations, input joint data file
			mcs800	e55075.exc	1KB	12/1/98 4:42 PM	Tptpln, 800 simulations, input excavation file
				G050aa.mkg	1KB	12/23/98 3:13 PM	Tptpln, 800 simulations, input grid file
				K050aa.ana	2KB	3/12/01 6:15 PM	Tptpln, 800 simulations, input summary file
				K050AA.bsd	557KB	3/14/01 2:25 PM	Tptpln, 800 simulations, output file for block size distribution
				K050AA.kbo	21KB	3/14/01 2:22 PM	Tptpln, 800 simulations, output file for key block information
				TplnAA.den	1KB	12/1/98 4:36 PM	Tptpln, 800 simulations, input density file
				Tplnaa.prb	2KB	8/17/00 8:30 AM	Tptpln, 800 simulations, input joint data file

Table I-1. Drift Degradation Calculation Computer File Information (Continued)

Main Directory	Sub-Directory		File Name	File Size	File Date and Time	Brief Description
Terzaghi Correction	Calculation Files		Correction Factor Comparison.xls	1,062KB	3/20/01 11:14 AM	Comparison of original Terzaghi correction factors for Joint Set 1 (vertical) and the subhorizontal joint set
			New_Beta_Tptpll V1 - modified Terzaghi.xls	239KB	3/20/01 4:31 PM	Calculation of beta distribution parameters for modified Terzaghi correction, Tptpll
			New_Beta_Tptpmn V1 - modified Terzaghi.xls	5,028KB	3/20/01 4:41 PM	Calculation of beta distribution parameters for modified Terzaghi correction, Tptpmn
			tpll 75 Terzaghi res V1.xls	3,037KB	9/20/01 10:32 AM	Rock blocks cumulative frequency of occurrence, Tptpll, modified Terzaghi correction
			tpmn 75 Terzaghi res V1.xls	3,039KB	9/20/01 10:31 AM	Rock blocks cumulative frequency of occurrence, Tptpmn, modified Terzaghi correction
			Tptpll sub H Terzaghi.xls	62KB	9/20/01 10:12 AM	Calculated true spacing distribution with modified Terzaghi correction, Tptpll
			Tptpmn sub H Terzaghi.xls	854KB	9/20/01 10:11 AM	Calculated true spacing distribution with modified Terzaghi correction, Tptpmn
	DRKBA Inputs & Outputs	k022aa	e55075.exc	1KB	12/1/98 5:42 PM	Tptpmn, with Terzaghi correction, input excavation file
			G022aa.mkg	1KB	12/23/98 4:06 PM	Tptpmn, with Terzaghi correction, input grid file
			K022aa.ana	2KB	9/15/99 9:31 AM	Tptpmn, with Terzaghi correction, input summary file
			K022AA.bsd	554KB	3/22/01 10:11 PM	Tptpmn, with Terzaghi correction, output file for block size distribution
			K022AA.kbo	31KB	3/22/01 10:05 PM	Tptpmn, with Terzaghi correction, output file for key block information
			TpmnAA.den	1KB	12/9/98 3:39 PM	Tptpmn, with Terzaghi correction, input density file
			Tpmnaa.prb	2KB	3/22/01 2:16 PM	Tptpmn, with Terzaghi correction, input joint data file
		k036aa	e55075.exc	1KB	12/1/98 4:42 PM	Tptpll, with Terzaghi correction, input excavation file
			G036aa.mkg	1KB	12/23/98 3:09 PM	Tptpll, with Terzaghi correction, input grid file

Table I-1. Drift Degradation Calculation Computer File Information (Continued)

Main Directory	Sub-Directory		File Name	File Size	File Date and Time	Brief Description
Terzaghi Correction	DRKBA Inputs & Outputs	k036aa	K036aa.ana	2KB	8/2/99 2:25 PM	Tptpll, with Terzaghi correction, input summary file
			K036AA.bsd	554KB	3/21/01 12:11 PM	Tptpll, with Terzaghi correction, output file for block size distribution
			K036AA.kbo	4KB	3/21/01 12:02 PM	Tptpll, with Terzaghi correction, output file for key block information
			TpllAA.den	1KB	12/9/98 2:39 PM	Tptpll, with Terzaghi correction, input density file
			Tpllaa.prb	2KB	3/20/01 4:37 PM	Tptpll, with Terzaghi correction, input joint data file

Notes:
M = joint radius multiplier (i.e., a multiplier of fracture trace lengths supplied from field data).
All calculation files were created using *Excel 97 SR-2* (see Section 4.2) and have the file name extension, *.xls*.
All DRKBA input and output files (extensions *.exc*, *.mkg*, *.den*, *.prb*, *.ana*, *.bsd*, and *.kbo*) are ASCII text files.